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EDIN DESIGN STUDY
ALTERNATE SPACE SHUTTLE BOOSTER REPLACEMENT CONCEPTS
VOLUME II - DESIGN SIMULATION RESULTS

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Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Johnson Space Center
Houston, Texas 77058

January 1976

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FOREWORD

This report is a technical assessment of a Shuttle-based launch system consisting of the Shuttle Orbiter, the external tank, and a recoverable liquid rocket booster system replacing the solid rocket booster system. This report was prepared for Johnson Space Center under Contract NAS9-14520. This study was conducted under the direction of Mr. Robert W. Abel, the technical monitor and H. P. Davis, chief of the Future Programs Office.

Compilation and publication of this assessment involved the time, effort and cooperation of a number of organizations and individuals. NASA personnel directed the study and defined design requirements and constraints. The actual computations and the majority of analysis used to generate the report were provided by the Sigma Corporation. Willie E. Heineman of EW2 checked vehicle weights and provided a number of the weight algorithms.

INTRODUCTION

The use of a recoverable liquid rocket booster (LRB) system to replace the existing solid rocket booster (SRB) system for the Shuttle offers the potential of extending the payload capability and of cost saving by recovery and re-use of the LRB with a minimum of refurbishment cost. The concept uses the basic Orbiter modified to include a weight penalty to account for the additional structure necessary to accommodate the increased payload and the Shuttle ET modified to account for deletion of the SRB/ET attachments and scaled according to a constant mass fraction. Some modification of the ET would be required to take thrust loads longitudinally along the tank rather than laterally through the tank. Two different types of LRB were investigated. One consisted of three and four up-rated F-1 engines, while the other was powered by high-pressure LOX/RP engines based on those proposed by Mr. Rudi Beichel of Systems Development Corporation. The LRB is mounted aft of the ET and is jettisoned at booster engine cut-off (BECO) and recovered for re-use.

The present study, designated EDIN05, was initiated for the purpose of assessing this LRB concept. The study, based on information contained in References 1 through 6, was performed using EDIN software and hardware and represents a joint effort between NASA and Sigma Corporation. The NASA Engineering Analysis Division and the Future Programs Office were involved in defining design requirements and constraints. Sigma Corporation developed the simulation procedures and supported the engineering analysis and computations.

Historical weight estimating relationships were developed for the LRB using Saturn technology and modified as required to support the EDIN05 study. Mission performance was computed using February 1975 Shuttle configuration groundrules to allow reasonable comparison of the existing Shuttle with the EDIN05 designs. The launch trajectory was constrained to pass through both the RTLS/AOA and main engine cut-off (MECO) points of the Shuttle Reference Mission 1. Performance analysis is based on a point design trajectory model which optimizes initial tilt rate and exo-atmospheric pitch profile. A gravity turn was employed during the boost phase in place of the Shuttle angle-of-attack profile. Engine throttling add/or shutdown was used to constrain dynamic pressure and/or longitudinal acceleration where necessary. Four basic configurations were investigated: a parallel-burn vehicle with an F-1 engine-powered LRB; a parallel-burn vehicle with a high-pressure engine-powered LRB; a series-burn vehicle with

a high-pressure engine-powered LRB. The relative sizes of the LRB and the ET are optimized to minimize GLOW in most cases.

This report comprises two volumes. Volume I contains an engineering analysis of each simulation performed, a description of the simulation programs and procedures, and a discussion of the LRB weight estimating relationships. Volume II presents the detailed results of the simulations, including weight statements, trajectory plots, and mass properties breakdowns.

DISCUSSION OF RESULTS

Configuration Descriptions

Four basic configurations were investigated in the EDIN05 design series:

1. A parallel burn vehicle with an F-1 engine-powered LRB.
2. A parallel burn vehicle with a high-pressure engine powered LRB.
3. A series burn vehicle with an F-1 engine-powered LRB.
4. A series burn vehicle with a high-pressure engine-powered LRB.

The EDIN05 study series comprised ten individual design simulations, which are briefly described below.

STUDY NO.	
EDIN0501	LRB sized for three F-1, ET resized to minimize GLOW for 100K up-payload; parallel burn.
EDIN0502A	EDIN0501 LRB modified for seven 680K sea-level thrust high - Pc engine propulsion system, EDIN0501 ET, maximum payload determined, parallel burn.
EDIN0502B	EDIN0502A LRB, ET resized to maximize payload, parallel burn.
EDIN0503	EDIN0501 LRB modified for six 800K sea-level thrust high-Pc engine propulsion system, EDIN0501 ET maximum payload determined; parallel burn.
EDIN0504	LRB sized for optimum T/W using rubber high-Pc engines based on 800K Beichel, ET resized to minimize GLOW for 140K up-payload; parallel burn.
EDIN0504A	LRB sized for optimum T/W using rubber high-Pc engines based on 800K Beichel, ET resized to minimize GLOW for 150K up-payload; parallel burn.
EDIN0504B	EDIN0504A LRB modified for three F-1, EDIN0504A ET, maximum payload determined; parallel burn.
EDIN0504C	LRB sized for optimum T/W using rubber high-Pc engines based on 800K Beichel, ET resized to minimize GLOW for 150K up-payload; series burn.
EDIN0504D	EDIN0504C LRB modified for four F-1, EDIN0504C ET, maximum payload determined; parallel burn.
EDIN0505	LRB sized for four F-1, ET resized to minimize GLOW for 100K up-payload; series burn.

EDIN05 RESULTS SUMMARY

	SHUTTLE	501	502A	502B	503	504	504A	504B	504C	504D	505
LRB	SRB	Sized for 3 F-1	501 w/ (7) 680K Hi-Pc	501 w/ (6) 800K Hi-Pc	501 w/ (6) 800K Hi-Pc	Sized for opt. T/W Hi-Pc	Sized for opt. T/W Hi-Pc	504A w/ 3 F-1	Sized for opt. T/W Hi-Pc	504C w/ 4 F-1	Sized for 4 F-1
ET	-	R	501	R	501	R	R	504A	R	504C	R
PL	65K	100K	D	M	D	140K	150K	D	150K	D	100K
TYPE	P	P	P	P	P	P	P	P	S	S	S
GLOW	4.203M	4.835M	4.817M	4.928M	4.698M	4.261M	4.804M	4.598M	4.587M	4.344M	4.795M
T/W	1.491	1.240	1.236	1.209	1.283	1.236	1.350	1.308	1.345	1.479	1.340
LRB LIFT-OFF	2.327M	2.760M	2.693M	2.693M	2.569M	2.055M	2.562M	2.428M	2.898M	2.760M	3.186M
LRB PROPELLANT	2.019M	2.506M	2.459M	2.459M	2.335M	1.855M	2.333M	2.180M	2.642M	2.468M	2.919M
LRB INERT	309K	254K	234K	234K	234K	200K	228K	248K	256K	292K	265K
ET LIFT-OFF	1.626M	1.805M	1.805M	1.911M	1.805M	1.879M	1.905M	1.905M	1.351M	1.324M	1.322M
ET PROPELLANT	1.540M	1.707M	07M	1.807M	1.707M	1.777M	1.801M	1.801M	1.276M	1.248M	1.251M
ET INERT	86.3K	98.0K	98.0K	104.1K	98.0K	102.5K	103.9K	103.9K	75.2K	75.2K	73.0K
PAYLOAD	65K	100K	132K	137K	136K	140K	150K	78.5K	150K	73.3K	100K

D - Determined
M - Maximized
P - Parallel Burn
R - Resized
S - Series Burn

SIGMA CORPORATION

EDIN0501 DESIGN

SIMULATION RESULTS

FORECASTER: EDIN DESIGN CENTER — DATE: 22 SEP 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC — TIME: 19:06
STUDY NO: EDIN0501

CONCEPT: A 33.0 FT. DIAMETER RECOVERABLE STAGE USING THREE F-1 ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR REPLACEMENT OF THE SOLID ROCKET BOOSTERS.

MISSION: 100000.0 LB PAYLOAD
DUE EAST LAUNCH FROM ETR
A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL MILE REFERENCE ORBIT.
A 100 FPS RCS TRANSLATION DELTA VeL.

TRAJECTORY: DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH PROFILE AND INITIAL TILT RATE.
- MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS/AOA
- END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO

ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY ONE F1 ENGINE SHUTDOWN AND/OR SSME THROTTLING.
- MAX DYNAMIC PRESSURE = 650.0 PSF
- MAX ACCELERATION = 3.0 G

PROPULSION: LRB: THREE F-1 ENGINES RATED AS FOLLOWS:
- THRUST(SL) = 1606788.5 LBS
- THRUST(VAC) = 1748060.0 LBS
- ISP(SL) = 266.01 SEC.
- ISP(VAC) = 289.40 SEC.
- FLOWRATE = 6040.2 LB/SEC
- EXIT AREA = 66.763 SQ FT
- MIX RATIO = 2.27:1

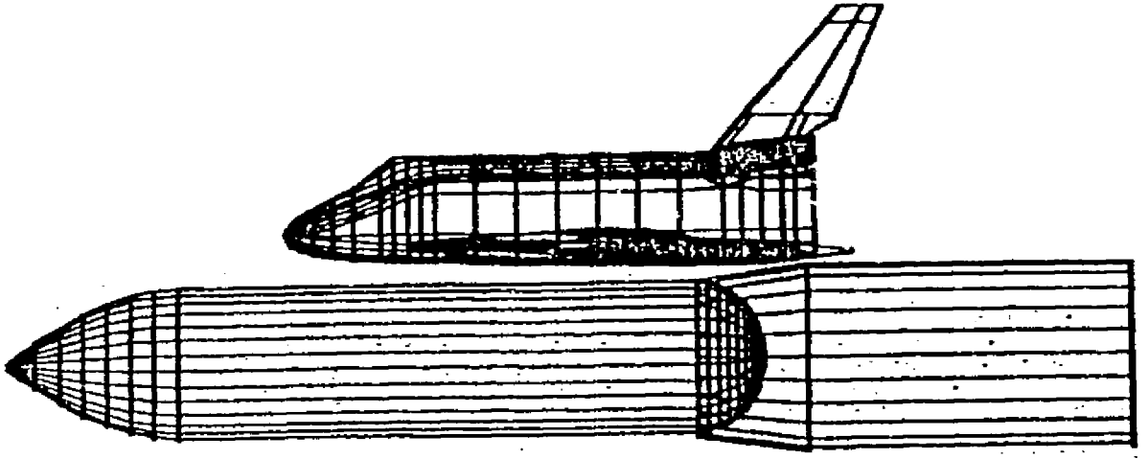
ORBITER: THREE SSME ENGINES RATED AS FOLLOWS:
- THRUST(SL) = 375000.00 LBS
- THRUST(VAC) = 470000.00 LBS
- THROTTLE = 1.09 TO .500
- ISP(SL) = 363.20 SEC
- ISP(VAC) = 455.20 SEC
- FLOWRATE = 1032.5 LB/SEC
- EXIT AREA = 44.896 SQ FT
- MIX RATIO = 6.00:1

AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
- REF AREA = 2557.0 SQ FT

STRUCTURE: ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND INCREASED UP PAYLOADS.

MASS PROPERTIES: MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC ASSUMPTIONS.
- LRB: WERS BASED ON SATURN TECHNOLOGY.
- ET: FIXED MASS FRACTION DISTRIBUTED IN ACCORDANCE WITH SHUTTLE ET WEIGHT STATEMENT.
- ORBITER: FEB 1975 SHUTTLE WITH MODS FOR INCREASED UP PAYLOAD.

EDIN0501 DESIGN SIMULATION RESULTS



WEIGHTS SUMMARY REPORT

GLOW		4852515.12
ET LIFT-OFF WEIGHT		1805486.73
ET INERT WEIGHT	98039.18	
ET PROPELLANT	1707527.58	
LRB LIFT-OFF WEIGHT		2759774.62
LRB INERT WEIGHT	254013.13	
LRB PROPELLANT	2505710.78	
ORBITER LIFT-OFF WEIGHT		287254.00
ORBITER INERT WEIGHT	187254.00	
PAYLOAD	100000.00	

ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2362.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	19874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	28054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	3908.	
PRIME POWER	2929.	
ELECTRICAL CONVERSION	6960.	
HYDRAULIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 100K PAYLD	390.	
ORBITER EMPTY WEIGHT		151715.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1840.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16149.	
ORBITER INERT WEIGHT		187254.
PAYLOAD		100000.
ORBITER PRELAUNCH WEIGHT		287254.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		16260.
BHD	79.	
FWD FRAME	51.	
FWD OGIVE	1342.	
AFT OGIVE	4511.	
XT 745 FRAME	313.	
BARREL	2917.	
INTERTANK FRAME	1064.	
AFT DOME	3469.	
SLOSH BAFFLES	2514.	
INTERTANK		12708.
MACHINED BARREL PNLS	5088.	
SK/STGR BARREL PNLS	5500.	
STABILIZING FRAMES(4)	1505.	
SRB THRST XT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	68.	
BARREL PNLS SPLICES (8)	113.	
FRAME STABLIZERS	244.	
ET ASSY FASTENERS	191.	

LH2 TANK		39888.
FWD DOME	1902.	
XT 1129.9 FRAME	1877.	
BARREL NO.4	6525.	
XT 1377 FRAME	655.	
BARREL NO.3	6559.	
XT 1624 FRAME	655.	
BARREL NO.2	6563.	
XT 1871 FRAME	2056.	
BARREL NO.1	6942.	
XT 2058 FRAME	3929.	
AFT DOME	2225.	
THERMAL PROTECTION		7729.
LOX TANK	1657.	
INTERTANK	1720.	
LH2 TANK	4037.	
PROP (MECH+ELEC)	314.	
PROPULSION AND MECHANICAL SYSTEMS		4504.
LOX FEED SYS	1926.	
LOX ANTIGEYER SYS	181.	
LOX VENT SYS	101.	
LOX PRESS. SYS	219.	
LH2 FEED SYS	551.	
LH2 RECIR. SYS	36.	
LH2 VENT SYS	153.	
LH2 PRESS. SYS	162.	
HELIUM INJ. SYS	25.	
INTERTANK PURGE SYS	95.	
HAZARD GAS DETECTION SYS	10.	
FAIRINGS AND CONDUIT	407.	
LINE SUPTS. AND ATTACHS.	637.	
ELECTRICAL SYSTEM		278.
ET WIRING ASSY	188.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	17.	
CABLING ATTACHS.+SENSOR SUPTS.	73.	
ORB/SRB ATTACHMENTS		5358.
ORBITER SUPPORTS	3677.	
UMBILICAL BEAM	754.	
ORB/ET ATTACH FTGS	280.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	647.	
MANUFACTURING VARIATION WT.		506.
EMPTY WEIGHT		87230.
UNUSABLE FLUIDS		486.
LH2 IN TANK	273.	
LH2 IN LINE	56.	
LOX IN LINE	157.	
PRE-PRESS.+INFLIGHT GASES		4405.
GH2	1145.	
GOX	3223.	
HELIUM	37.	
SEPARATION HARDWARE		6.
SRB SUPPORTS	0.	
ORB FITTINGS	6.	
FLT PERF RES		5912.
ET INERT WT		98039.
MAIN PROPELLANTS		1707448.
LOX	1463527.	
LH2	243921.	
ET LIFT-OFF WEIGHT		1805487.
MASS FRACTION		.9490

LIQUID ROCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		93058.
INTEGRAL LOX TANK	20679.	
INTEGRAL FUEL TANK	14022.	
INTERSTAGE	8583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	33615.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		2189.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1248.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		799.
ELECTRICAL SYSTEM	684.	
CONTROL SYSTEM	115.	
INSTRUMENATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		87977.
ENGINES (DRY)	57114.	
ACCESSORIES	416.	
GIMBAL SYSTEM	5283.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	8389.	
OXIDIZER SYSTEM	12419.	
SEPARATION AND RECOVERY SYSTEM		16665.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	5724.	
FLOATATION SYSTEM	104.	
RECOVERY AIDS	108.	
FITTINGS AND SUPPORTS	197.	
RETRO SYS (100 F/S DEL V)	3174.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		209125.
CONTINGENCY		0.
EMPTY WEIGHT		209125.
PROPELLANT RESIDUALS		40575.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	3871.	
TRAPPED FUEL TANK GASES	3440.	
FROST TRAPPED	434.	
TRAPPED FUEL	12958.	
TRAPPED LOX	18073.	
IN-FLIGHT LOSSES		4313.
FUEL LOSSES	2084.	
LOX LOSSES	2229.	
MAIN PROPELLANTS		2505762.
FUEL	766288.	
LOX	1739474.	
BLOW		2759775.
MASS FRACTION (BASED ON INERT WT)		.9080

ORBITER WT	287254.0
ET WEIGHT	1805486.7
LRB STAGE WT	2759774.7
GLOW	4852515.4
EFFECTIVE STG 1 LAMBDA	.92138
EFFECTIVE STG 2 LAMBDA	.92652

CONVERGENCE DATA:

GLOW	4852515.	
TARGET PAYLOAD	100000.	
ACTUAL PAYLOAD		99970.
PAYLOAD DELTA		-29.6
PAYLOAD BIAS		.0
TOTAL VIDEAL	30193.0	
STAGE 1 VIDEAL		9144.5
STAGE 2 VIDEAL		21048.5
TOTAL PROPELLANT	4213238.	
LRB PROPELLANT		2505711.
ET PROPELLANT		1707528.

STAGE 1 SIZING DATA

AVERAGE SP. IMP.	298.98
LIFT-OFF T/W	1.240
MAXIMUM Q	605.3
TIME AT MAX Q	80.0
STG 1 MAX LF	3.00
TIME AT MAX LF	132.8
EFF WDOT/EVENT 1	21460.9
EFF WDOT/EVENT 2	15456.7

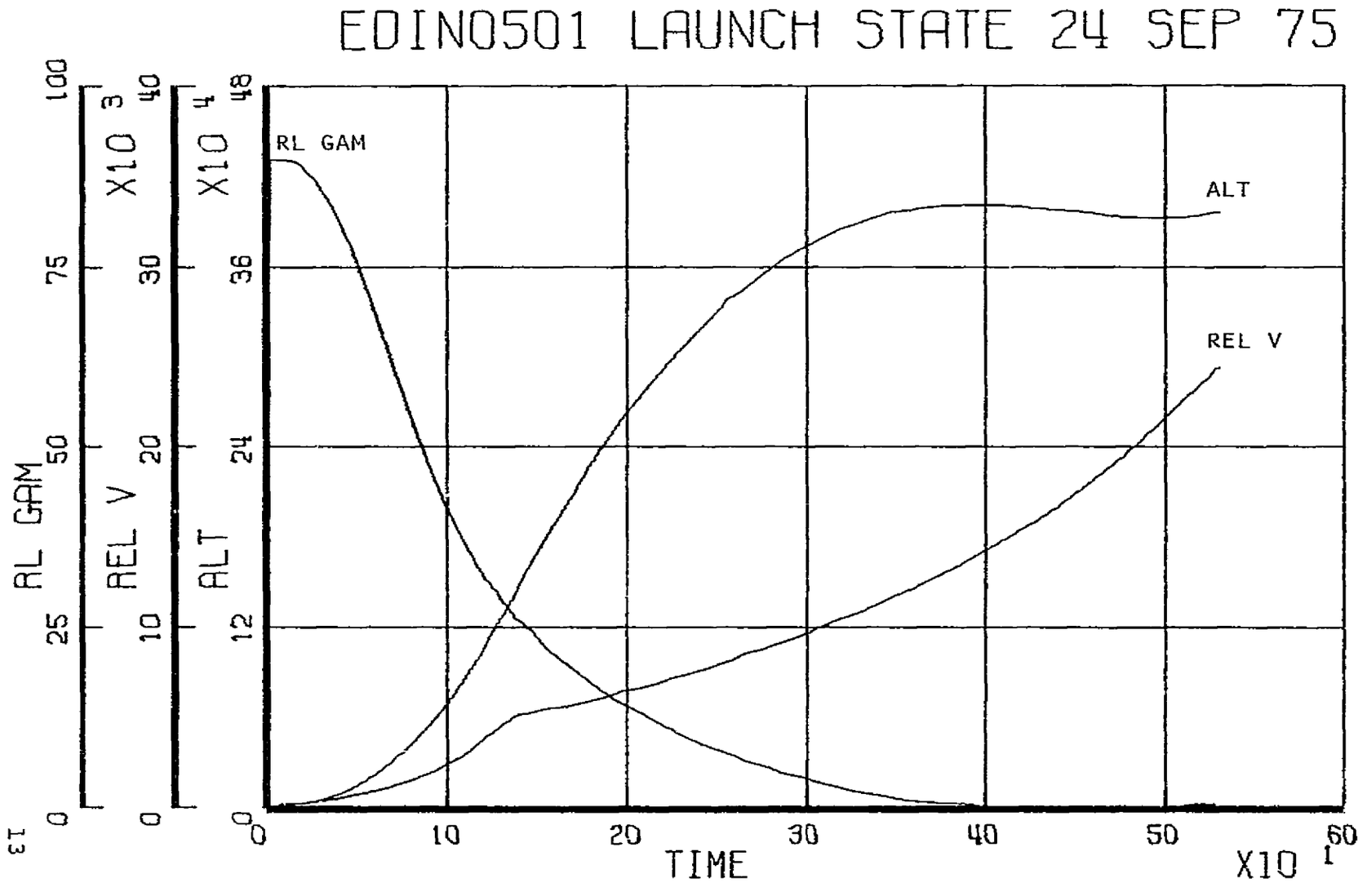
STAGING CONDITIONS:

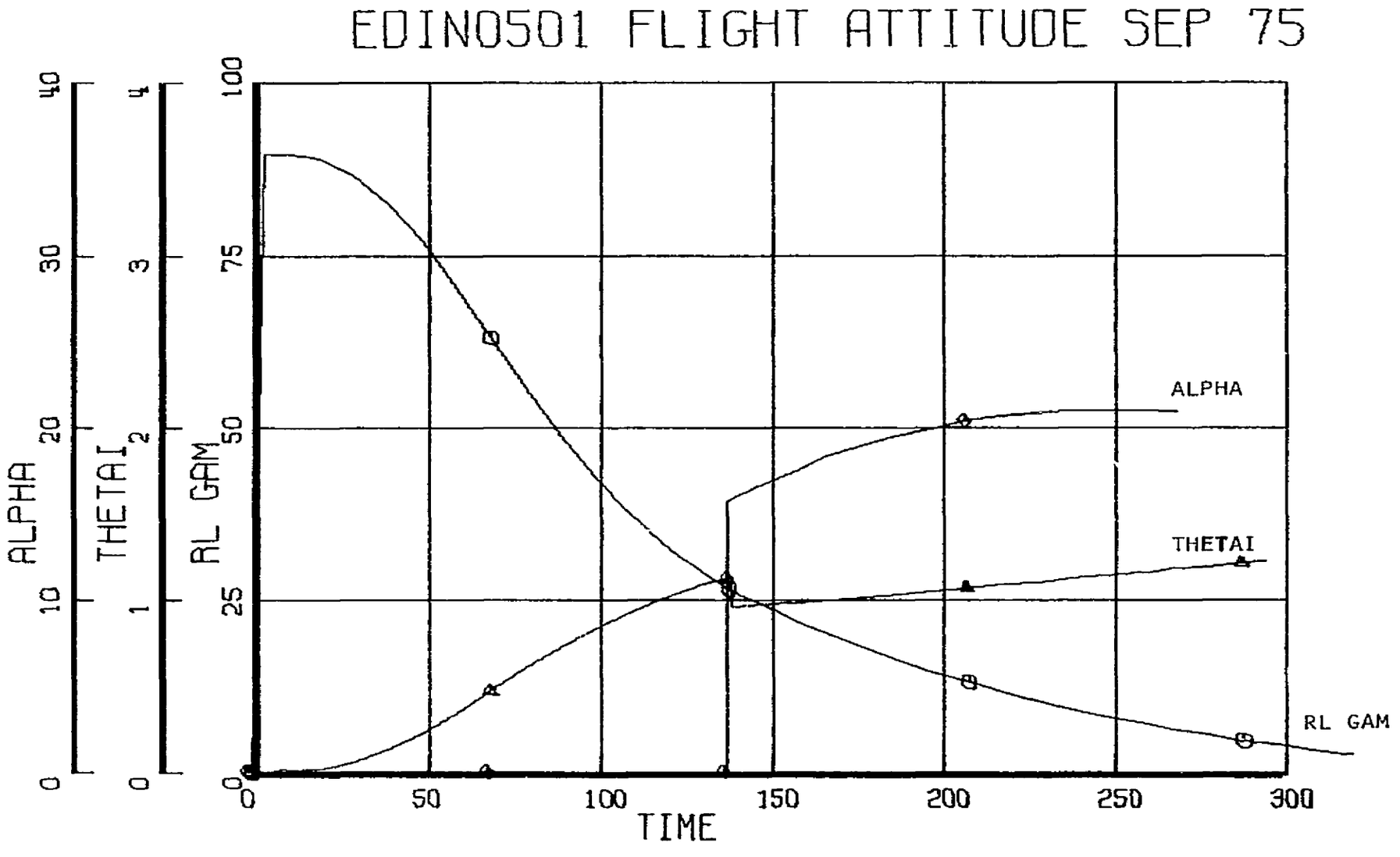
WEIGHT	1875506.
REL VELOCITY (FPS)	5136.7
REL F.P. ANGLE (DEG)	26.05
ALTITUDE (FT)	146941.
TIME (SEC)	141.02
ATT AFTER STG (DEG)	.92

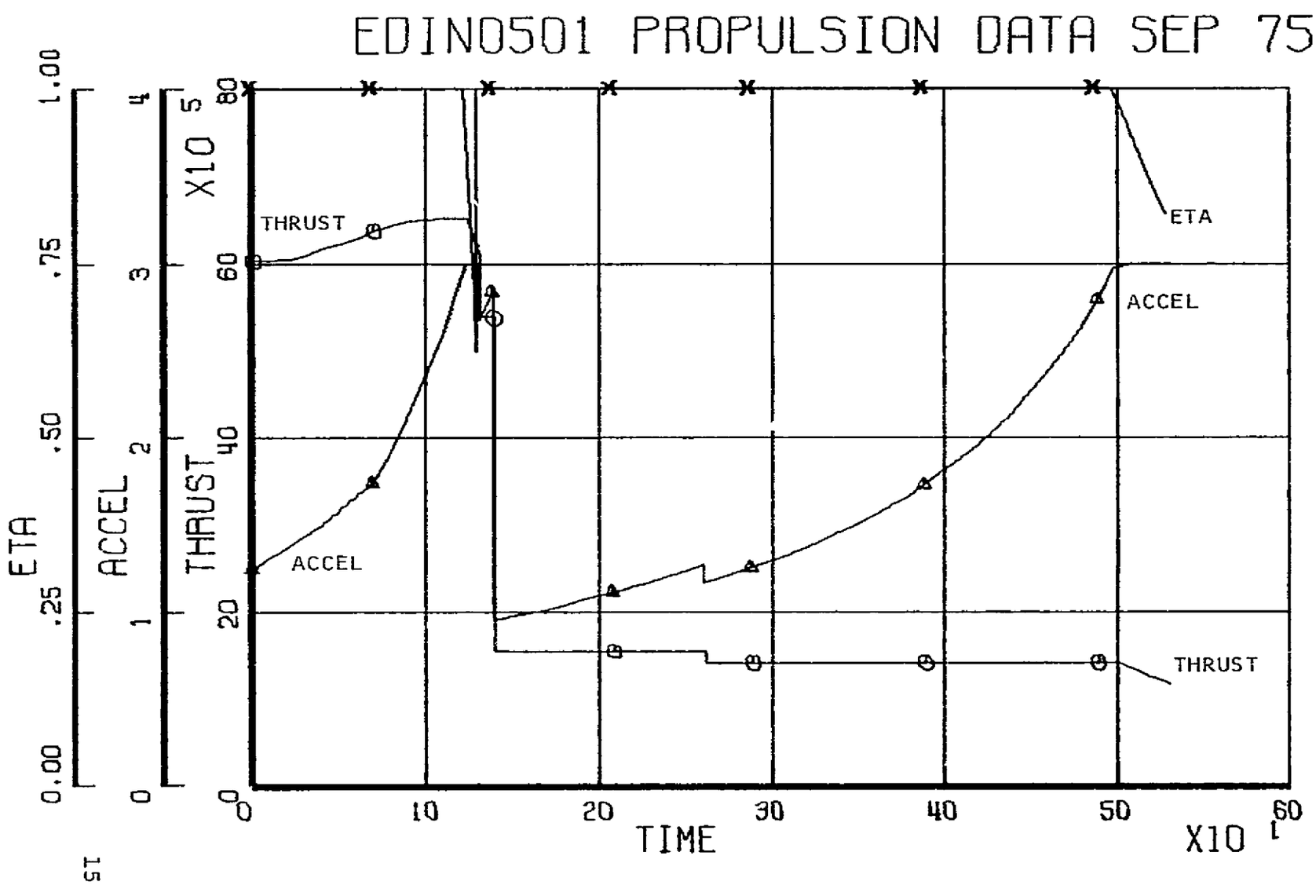
MISSION SUMMARY: SEPTEMBER 18, 1975

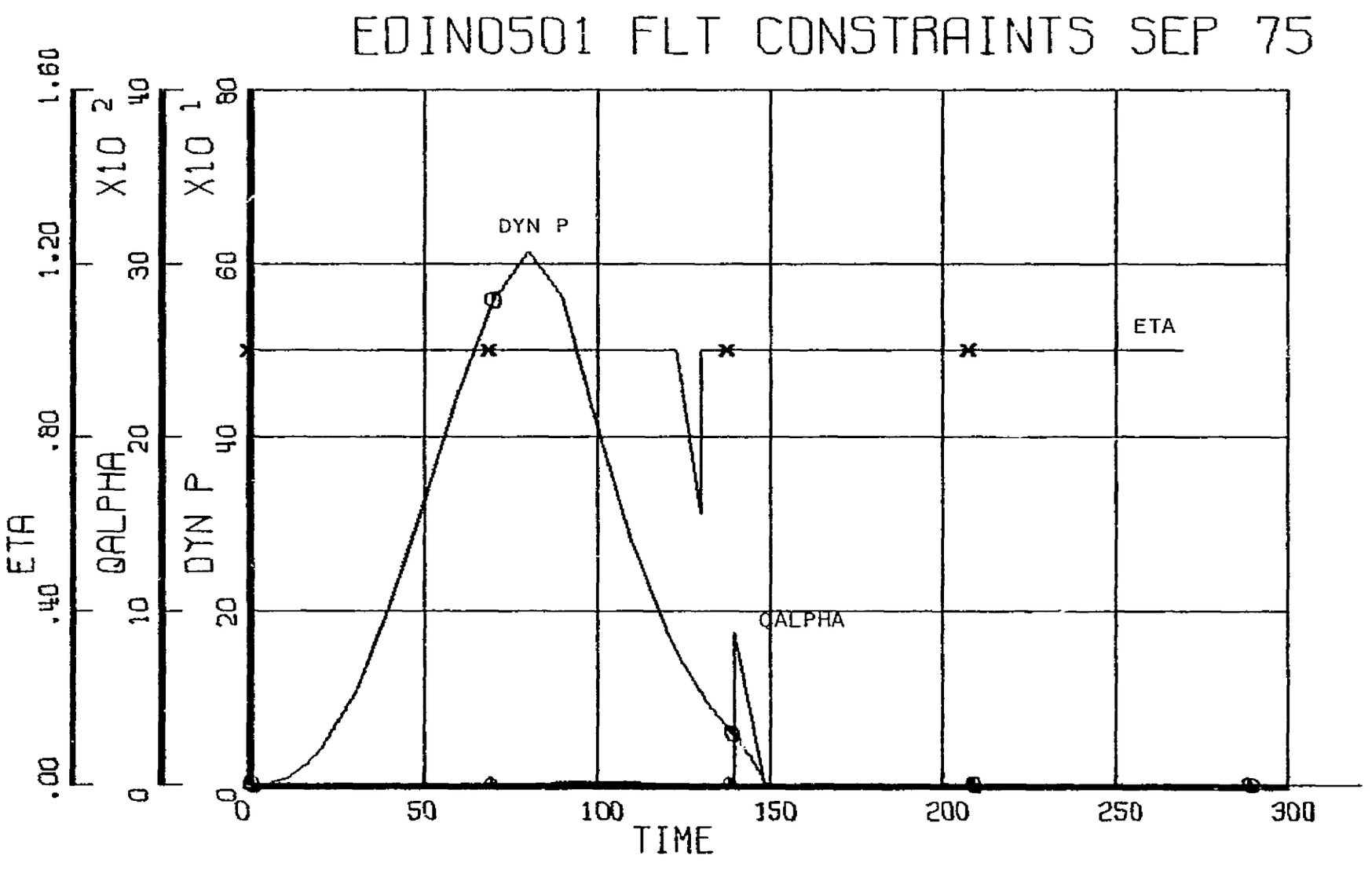
PARAMETER	EVENT 1	EVENT 2	EVENT 3	EVENT 4	EVENT 5
TIME (SEC)	132.8	141.0	262.4	532.0	513.7
ALTITUDE (K FT)	128.8	146.9	348.6	394.5	0
REL VELOCITY (100 FPS)	45.3	51.4	81.4	243.0	2.1
REL GAMMA (DEG)	28.6	26.0	8.27	.528	-89.8
WEIGHT (K LBS)	4852.5	2002.4	1621.5	1211.8	254.0
WEIGHT DROP (K LBS)	0	254.0	0	0	-
THROW WEIGHT (K LBS)	2002.4	1621.5	1211.8	385.26	-
CUM VIDEAL (100 FPS)		91.44	134.1	301.9	-
DOWNRANGE (NMI)	23.45	29.99	169.2	888.3	161.7

EVENT 1 ONE F-1 ENGINE SHUTDOWN
EVENT 2 BECO/SEPARATION
EVENT 3 RTLS/ABA CONSTRAINT
EVENT 4 MECO/INJECTION
EVENT 5 LRB TOUCHDOWN


EDIN0501 LAUNCH STATE 24 SEP 75
RL GAM
ALT
REL V
RL GAM
REL V
X10 3
ALT
X10 4
TIME
X10 1
0
25
50
75
100
10
20
30
40
12
24
36
48
60


EDIN0501 FLIGHT ATTITUDE SEP 75
ALPHA
THETAI
RL GAM
TIME
0
10
20
30
40
0
1
2
3
4
0
25
50
75
100
0
50
100
150
200
250
300
ALPHA
THETAI
RL GAM


EDIN0501 PROPULSION DATA SEP 75
ETA
ACCEL
THRUST
X10 5
TIME
X10
THRUST
ACCEL
ETA
ACCEL
THRUST
0.00
.25
.50
.75
1.00
0
1
2
3
4
0
20
40
60
80
0
10
20
30
40
50
60


EDIN0501 FLT CONSTRAINTS SEP 75
ETA
QALPHA X10 2
DYN P X10 1
TIME
DYN P
ETA
QALPHA
.00
.40
.80
1.20
1.60
0
10
20
30
40
0
20
40
60
80
0
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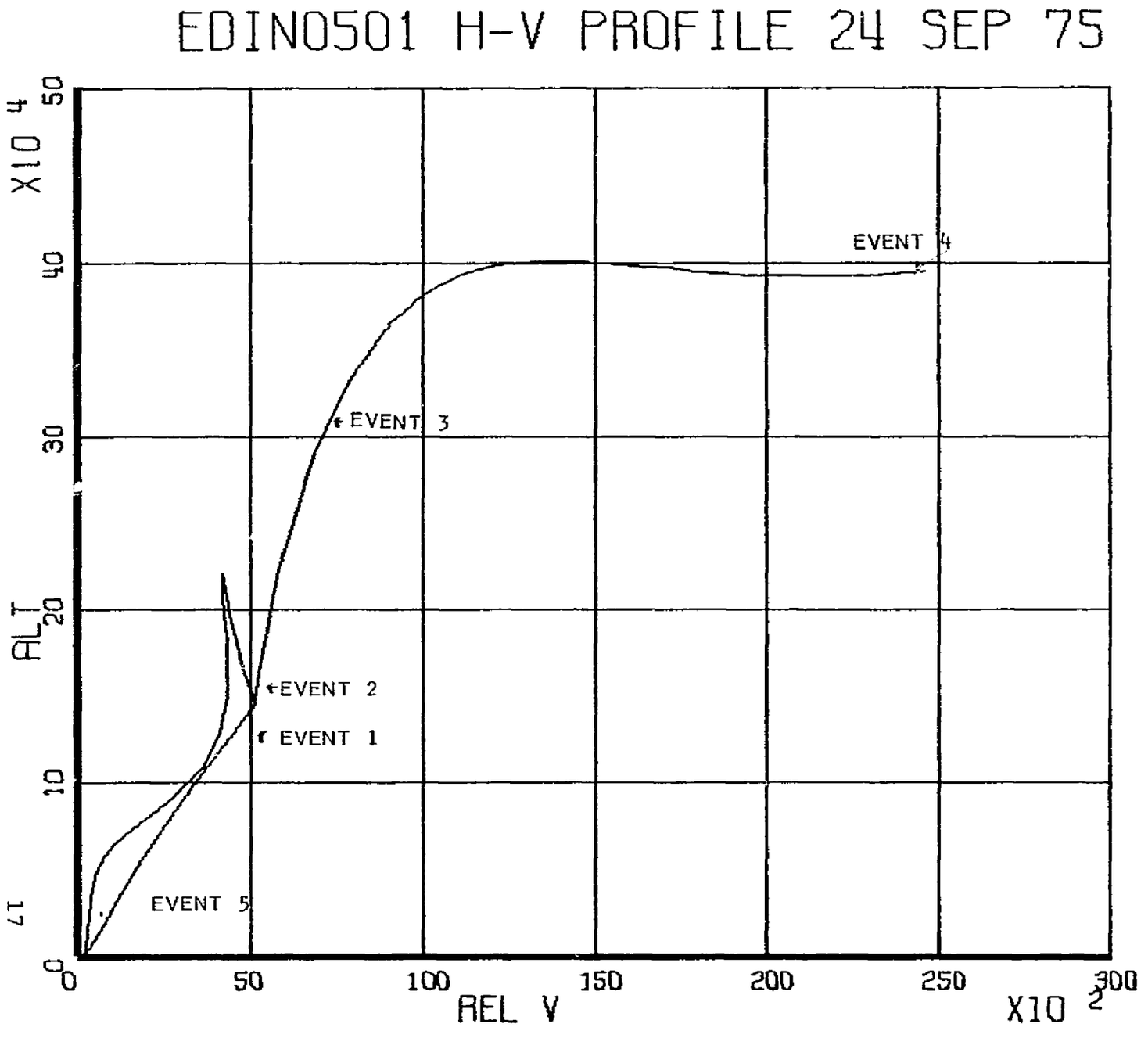
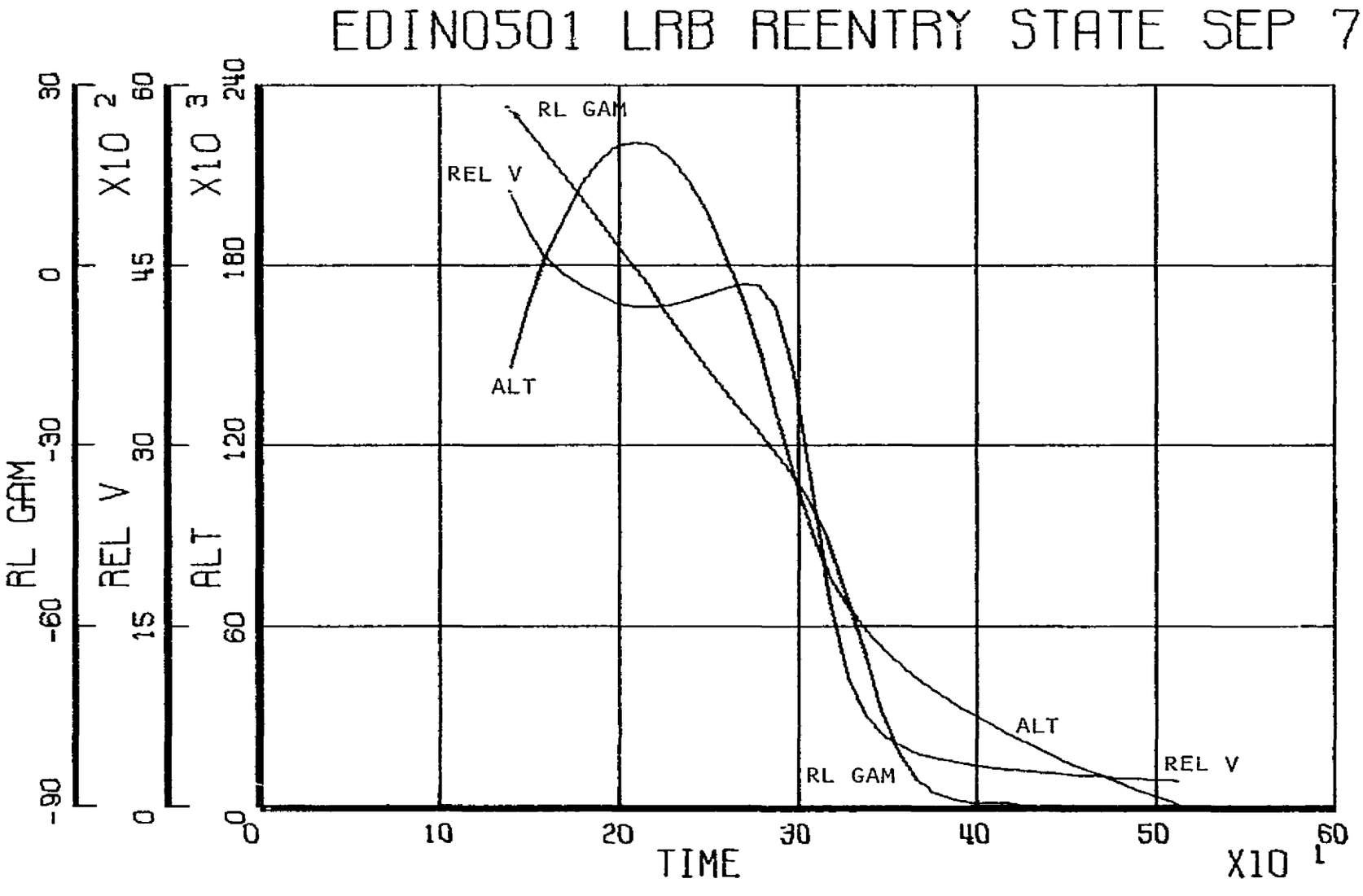
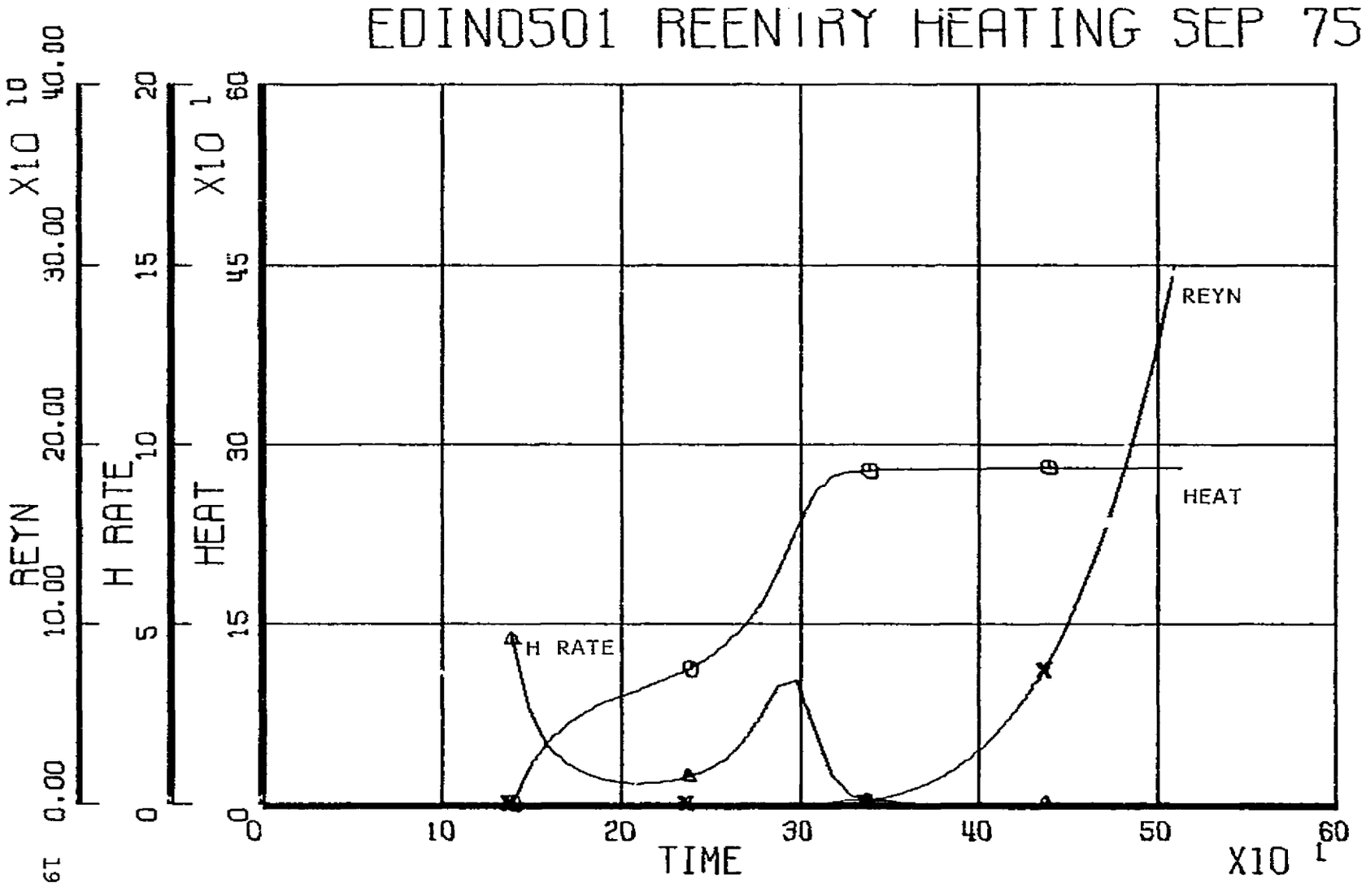
100
150
200
250
300


EDIN0501 H-V PROFILE 24 SEP 75
X10 4
50
40
30
20
10
0
ALT
17
EVENT 4
EVENT 3
EVENT 2
EVENT 1
EVENT 5
0
50
100
150
200
250
300
REL V
X10 2


EDIN0501 LRB REENTRY STATE SEP 75
RL GAM
REL V
ALT
X10 2
X10 3
30
0
-30
-60
-90
60
45
30
15
0
240
180
120
60
0
RL GAM
REL V
ALT
0
10
20
30
40
50
60
TIME
X10 1


EDIN0501 REENIRY HEATING SEP 75
REYN
X10 10
40.00
30.00
20.00
10.00
0.00
H RATE
20
15
10
5
0
HEAT
X10 1
60
45
30
15
0
0
10
20
30
40
50
60
TIME
X10 1
REYN
HEAT
H RATE

```
.
**************************************************************************
MASS PROPERTIES SUMMARY                          DATE:22 SEP 75
FORECASTER: EDIN DESIGN CENTER
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC
STUDY NO: EDIN0501
**************************************************************************
.
.
ORBITER MASS PROPERTIES SUMMARY
.
.                        WEIGHT          X-CG          Y-CG          Z-CG
ORBITER EMPTY          151715.00       1135.90           .6        380.70
ORBITER INERT          187254.00       1135.90           .6        380.70
ORBITER LAUNCH         287254.00       1135.90           .6        380.70
.                         (LB)           (IN)          (IN)          (IN)
.
EXTERNAL TANK MASS PROPERTIES SUMMARY
.
.                        WEIGHT          X-CG          Y-CG          Z-CG
ET EMPTY                87235.55        674.76             0         79.77
ET INERT                98039.20        639.65             0         77.98
ET LAUNCH             1805487.11        160.14             0         64.29
.                         (LB)           (IN)          (IN)          (IN)
.
LIQUID ROCKET BOOSTER MASS PROPERTIES SUMMARY
.
.                        WEIGHT          X-CG          Y-CG          Z-CG
LRB EMPTY              209125.31       2002.42             0        102.30
LRB INERT              254013.13       1983.08             0         95.44
LRB LAUNCH            2759775.00       1786.27             0         66.44
.                         (LB)           (IN)          (IN)          (IN)
.
MISSION MASS PROPERTIES SUMMARY
.
.                        WEIGHT          X-CG          Y-CG          Z-CG
LAUNCH                4852516.0        1142.7           .04         84.24
PRE-BECO              1875507.1        650.77           .09         117.2
POST-BECO             1621494.0        442.06           .11         120.6
MECO                   385293.20       1009.6           .45         303.7
.                         (LB)           (IN)          (IN)          (IN)
```

ET COMPONENTS MASS PROPERTIES

LOXTNK

WT	=	16259.52			
XCG	=	14.26938	YCG =	.0000000	ZCG = 63.50000
IXX	=	55370.25	IYY =	96707.89	IZZ = 96707.89
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT 1

WT	=	16259.52			
XCG	=	14.26938	YCG =	.0000000	ZCG = 63.50000
IXX	=	55370.25	IYY =	96707.89	IZZ = 96707.89
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

INRTNK

WT	=	12707.69			
XCG	=	241.4819	YCG =	.0000000	ZCG = 63.50000
IXX	=	66622.65	IYY =	48128.65	IZZ = 48128.65
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT 2

WT	=	28967.21			
XCG	=	113.9457	YCG =	.0000000	ZCG = 63.50000
IXX	=	121992.9	IYY =	224317.8	IZZ = 224317.8
IXY	=	.0000000	IXZ =	-.4316805-03	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

LH2TNK

WT	=	39887.89			
XCG	=	998.8568	YCG =	.0000000	ZCG = 63.50000
IXX	=	185692.3	IYY =	980678.4	IZZ = 980679.3
IXY	=	.0000000	IXZ =	.6906888-02	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT 3

WT	=	68855.10			
XCG	=	626.5763	YCG =	.0000000	ZCG = 63.50000
IXX	=	311685.2	IYY =	4041238.	IZZ = 4041239.
IXY	=	.0000000	IXZ =	.6906888-02	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

THMPRT

WT	=	7728.909			
XCG	=	581.7517	YCG =	.0000000	ZCG = 63.50000
IXX	=	.1079201-03	IYY =	.0000000	IZZ = .0000000
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT 4

WT	=	76584.01			
XCG	=	622.0526	YCG =	.0000000	ZCG = 63.50000
IXX	=	311685.2	IYY =	4044252.	IZZ = 4044253.
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

PAMSYS
WT = 4503.560
XCG = 761.7655 YCG = .0000000 ZCG = 203.5000
IXX = .0000000 IYY = .0000000 IZZ = -.1381378-01
IXY = .0000000 IXZ = .1726722-02 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT 5
WT = 81087.57
XCG = 629.8122 YCG = .0000000 ZCG = 71.27552
IXX = 329679.3 IYY = 4080166. IZZ = 4062173.
IXY = .0000000 IXZ = 17957.14 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

ELCSYS
WT = 278.4903
XCG = 964.8298 YCG = .0000000 ZCG = 203.5000
IXX = .0000000 IYY = .0000000 IZZ = .0000000
IXY = .0000000 IXZ = -.1079201-03 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT 6
WT = 81366.06
XCG = 630.9588 YCG = .0000000 ZCG = 71.72809
IXX = 330726.6 IYY = 4087937. IZZ = 4068896.
IXY = .0000000 IXZ = 20610.71 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

ORBATT
WT = 5357.566
XCG = 1341.322 YCG = .0000000 ZCG = 203.5000
IXX = -.8633610-03 IYY = .5525511-01 IZZ = .0000000
IXY = .0000000 IXZ = -.3453444-02 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT 7
WT = 86723.62
XCG = 674.8433 YCG = .0000000 ZCG = 79.86862
IXX = 349565.3 IYY = 4654253. IZZ = 4616374.
IXY = .0000000 IXZ = 122167.5 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

MNFVAR
WT = 511.9267
XCG = 660.7822 YCG = .0000000 ZCG = 63.50000
IXX = .0000000 IYY = .0000000 IZZ = .0000000
IXY = .0000000 IXZ = -.1079201-03 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

EMTY 8
WT = 87235.55
XCG = 674.7608 YCG = .0000000 ZCG = 79.77257
IXX = 349594.7 IYY = 4654304. IZZ = 4616396.
IXY = .0000000 IXZ = 122192.8 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

RESLOX
WT = 3280.148
XCG = 55.43106 YCG = .0000000 ZCG = 63.50000
IXX = .0000000 IYY = .0000000 IZZ = -.5396006-04
IXY = .0000000 IXZ = .2698003-04 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT 9
WT = 90615.70
XCG = 651.6585 YCG = .0000000 ZCG = 79.16557
IXX = 349780.7 IYY = 4923893. IZZ = 4885799.
IXY = .0000000 IXZ = 129271.2 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

RESLH2
WT = 1511.464
XCG = 987.8803 YCG = .0000000 ZCG = 63.50000
IXX = .0000000 IYY = .0000000 IZZ = .0000000
IXY = .0000000 IXZ = .2158403-03 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT10
WT = 92127.16
XCG = 657.1747 YCG = .0000000 ZCG = 78.90855
IXX = 349859.4 IYY = 4960246. IZZ = 4922073.
IXY = .0000000 IXZ = 127581.1 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

FLTPFR
WT = 5912.040
XCG = 366.6134 YCG = .0000000 ZCG = 63.50000
IXX = .0000000 IYY = .0000000 IZZ = .0000000
IXY = .0000000 IXZ = .4316805-03 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

ENRT11
WT = 98039.20
XCG = 639.6530 YCG = .0000000 ZCG = 77.97937
IXX = 350144.1 IYY = 5061767. IZZ = 5023308.
IXY = .0000000 IXZ = 132949.7 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

LOXFUL
WT = 1463587.
XCG = 12.96441 YCG = .0000000 ZCG = 63.50000
IXX = .2762755-01 IYY = .2762755-01 IZZ = .0000000
IXY = .0000000 IXZ = -.6906888-02 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT12
WT = 1561566.
XCG = 52.30956 YCG = .0000000 ZCG = 64.40905
IXX = 354302.0 IYY = .1285482+08 IZZ = .1281221+08
IXY = .0000000 IXZ = 312908.9 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

```
LH2FUL
WT  =  243921.1
XCG =  850.4968        YCG =  .0000000        ZCG =  63.50000
IXX =  .0000000        IYY =  .0000000        IZZ =  .0000000
IXY =  .0000000        IXZ =  .0000000        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

ETFL13
WT  =  1805487.
XCG =  160.1446        YCG =  .0000000        ZCG =  64.28624
IXX =  354339.6        IYY =  .4186551+08     IZZ =  .4182286+08
IXY =  .0000000        IXZ =  279868.7        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

LOX
WT  =  403926.1
XCG = -325.0305        YCG =  .0000000        ZCG =  63.50000
IXX =  .0000000        IYY = -.2210204        IZZ =  .0000000
IXY =  .0000000        IXZ = -.2762755-01     IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT14
WT  =  1401561.
XCG =  299.9707        YCG =  .0000000        ZCG =  64.51283
IXX =  354270.2        IYY =  .1542835+08     IZZ =  .1538577+08
IXY =  .0000000        IXZ =  237026.7        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

LH2
WT  =  67321.02
XCG =  444.5338        YCG =  .0000000        ZCG =  63.50000
IXX =  .1726722-02     IYY =  .0000000        IZZ =  .0000000
IXY =  .0000000        IXZ =  .0000000        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

ETBC15
WT  =  1334240.
XCG =  292.6766        YCG =  .0000000        ZCG =  64.56394
IXX =  354254.5        IYY =  .1510934+08     IZZ =  .1506678+08
IXY =  .0000000        IXZ =  239261.6        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000
```

LRB COMPONENTS MASS PROPERTIES

LOXTNK

WT =	20678.60				
XCG =	1658.737	YCG =	.0000000	ZCG =	63.50000
IXX =	110566.4	IYY =	69679.56	IZZ =	69679.56
IXY =	.0000000	IXZ =	.0000000	IYZ =	.0000000
ASF =	.0000000	VOL =	.0000000	AFR =	.0000000

SUBT 1

WT =	20678.60				
XCG =	1658.737	YCG =	.0000000	ZCG =	63.50000
IXX =	110566.4	IYY =	69679.56	IZZ =	69679.56
IXY =	.0000000	IXZ =	.0000000	IYZ =	.0000000
ASF =	.0000000	VOL =	.0000000	AFR =	.0000000

RPTANK

WT =	14021.99				
XCG =	2010.528	YCG =	.0000000	ZCG =	63.50000
IXX =	75212.80	IYY =	45538.83	IZZ =	45538.83
IXY =	.0000000	IXZ =	.0000000	IYZ =	.0000000
ASF =	.0000000	VOL =	.0000000	AFR =	.0000000

SUBT 2

WT =	34700.59				
XCG =	1800.890	YCG =	.0000000	ZCG =	63.50000
IXX =	185779.2	IYY =	338419.4	IZZ =	338419.4
IXY =	.0000000	IXZ =	.0000000	IYZ =	.0000000
ASF =	.0000000	VOL =	.0000000	AFR =	.0000000

INTSTG

WT =	8583.270				
XCG =	1448.402	YCG =	.0000000	ZCG =	63.50000
IXX =	90145.90	IYY =	60118.55	IZZ =	60118.55
IXY =	.0000000	IXZ =	-.1726722-02	IYZ =	.0000000
ASF =	.0000000	VOL =	.0000000	AFR =	.0000000

SUBT 3

WT =	43283.86				
XCG =	1730.991	YCG =	.0000000	ZCG =	63.50000
IXX =	275925.1	IYY =	583076.2	IZZ =	583075.7
IXY =	.0000000	IXZ =	.0000000	IYZ =	.0000000
ASF =	.0000000	VOL =	.0000000	AFR =	.0000000

AFTSKT

WT =	16159.43				
XCG =	2157.099	YCG =	.0000000	ZCG =	63.50000
IXX =	144423.6	IYY =	285024.4	IZZ =	285024.4
IXY =	.0000000	IXZ =	-.6906888-02	IYZ =	.0000000
ASF =	.0000000	VOL =	.0000000	AFR =	.0000000

SUBT 4

WT =	59443.29				
XCG =	1846.827	YCG =	.0000000	ZCG =	63.50000
IXX =	420348.7	IYY =	1329226.	IZZ =	1329226.
IXY =	.0000000	IXZ =	-.2762755-01	IYZ =	.0000000
ASF =	.0000000	VOL =	.0000000	AFR =	.0000000

```
THRSTR
WT  =  33615.19
XCG =  2100.257        YCG =   .0000000        ZCG =  63.50000
IXX =  142283.4        IYY =  71894.41         IZZ =  71895.29
IXY =  .0000000        IXZ =  .1381378-01      IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000         AFR =  .0000000

SUBT 5
WT  =  93058.48
XCG =  1938.373        YCG =   .0000000        ZCG =  63.50000
IXX =  562572.1        IYY =  1698788.         IZZ =  1698788.
IXY =  .0000000        IXZ = -.5525511-01      IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000         AFR =  .0000000

STBLZR
WT  =  6916.000
XCG =  1475.266        YCG =   .0000000        ZCG =  63.50000
IXX =  .0000000        IYY =  .0000000         IZZ =  .0000000
IXY =  .0000000        IXZ =  .0000000         IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000         AFR =  .0000000

SUBT 6
WT  =  99974.48
XCG =  1906.336        YCG =   .0000000        ZCG =  63.50000
IXX =  562572.1        IYY =  1996789.         IZZ =  1996790.
IXY =  .0000000        IXZ =  .0000000         IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000         AFR =  .0000000

TNKINS
WT  =  940.8276
XCG =  1875.934        YCG =   .0000000        ZCG =  63.50000
IXX =  .0000000        IYY = -.1381378-01      IZZ = -.1381378-01
IXY =  .0000000        IXZ = -.2158403-03      IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000         AFR =  .0000000

SUBT 7
WT  =  100915.3
XCG =  1906.053        YCG =   .0000000        ZCG =  63.50000
IXX =  562572.1        IYY =  1996976.         IZZ =  1996976.
IXY =  .0000000        IXZ =  .0000000         IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000         AFR =  .0000000

ABLMTL
WT  =  1248.377
XCG =  1807.739        YCG =   .0000000        ZCG =  261.5000
IXX =  .0000000        IYY = -.1381378-01      IZZ = -.1381378-01
IXY =  .0000000        IXZ =  .0000000         IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000         AFR =  .0000000

SUBT 8
WT  =  102163.7
XCG =  1904.851        YCG =   .0000000        ZCG =  65.91944
IXX =  573006.5        IYY =  2009983.         IZZ =  1999547.
IXY =  .0000000        IXZ = -5181.023         IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000         AFR =  .0000000
```

ELECSY
WT = 884.4820
XCG = 1807.739 YCG = .0000000 ZCG = 63.50000
IXX = .0000000 IYY = .0000000 IZZ = -.1381378-01
IXY = .0000000 IXZ = -.2158403-03 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT 9
WT = 102848.2
XCG = 1904.205 YCG = .0000000 ZCG = 65.90333
IXX = 573007.4 IYY = 2011367. IZZ = 2000931.
IXY = .0000000 IXZ = -5146.571 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

CONTSY
WT = 114.9930
XCG = 1421.539 YCG = .0000000 ZCG = 63.50000
IXX = .0000000 IYY = -.8633610-03 IZZ = -.8633610-03
IXY = .0000000 IXZ = .2698003-04 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT10
WT = 102963.2
XCG = 1903.666 YCG = .0000000 ZCG = 65.90065
IXX = 573007.5 IYY = 2017144. IZZ = 2006708.
IXY = .0000000 IXZ = -5117.811 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

INSTSY
WT = 1520.000
XCG = 1421.539 YCG = .0000000 ZCG = 63.50000
IXX = .0000000 IYY = .1381378-01 IZZ = .0000000
IXY = .0000000 IXZ = .0000000 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT11
WT = 104483.2
XCG = 1896.652 YCG = .0000000 ZCG = 65.86573
IXX = 573009.4 IYY = 2092296. IZZ = 2081857.
IXY = .0000000 IXZ = -4743.651 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

ENGNES
WT = 57114.00
XCG = 2214.257 YCG = .0000000 ZCG = 162.5000
IXX = 31949.99 IYY = 21301.06 IZZ = 21299.30
IXY = .0000000 IXZ = -.5525511-01 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT12
WT = 161597.2
XCG = 2008.905 YCG = .0000000 ZCG = 100.0196
IXX = 679389.7 IYY = 2992037. IZZ = 2907168.
IXY = .0000000 IXZ = 239884.3 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

ACCESS

WT	=	416.4000			
XCG	=	2214.257	YCG = .0000000	ZCG =	162.5000
IXX	=	.0000000	IYY = -.6906888-02	IZZ =	-.6906888-02
IXY	=	.0000000	IXZ = .4316805-03	IYZ =	.0000000
ASF	=	.0000000	VOL = .0000000	AFR =	.0000000

SUBT13

WT	=	162013.6			
XCG	=	2009.432	YCG = .0000000	ZCG =	100.1802
IXX	=	679739.7	IYY = 2996167.	IZZ =	2910945.
IXY	=	.0000000	IXZ = 241034.5	IYZ =	.0000000
ASF	=	.0000000	VOL = .0000000	AFR =	.0000000

GMBLSY

WT	=	5283.000			
XCG	=	2100.257	YCG = .0000000	ZCG =	162.5000
IXX	=	.0000000	IYY = .0000000	IZZ =	-.1105102
IXY	=	.0000000	IXZ = -.3453444-02	IYZ =	.0000000
ASF	=	.0000000	VOL = .0000000	AFR =	.0000000

SUBT14

WT	=	167296.6			
XCG	=	2012.301	YCG = .0000000	ZCG =	102.1482
IXX	=	684028.4	IYY = 3009566.	IZZ =	2920058.
IXY	=	.0000000	IXZ = 247284.9	IYZ =	.0000000
ASF	=	.0000000	VOL = .0000000	AFR =	.0000000

BHTSHD

WT	=	4356.000			
XCG	=	1985.940	YCG = .0000000	ZCG =	63.50000
IXX	=	.0000000	IYY = .0000000	IZZ =	.0000000
IXY	=	.0000000	IXZ = -.3453444-02	IYZ =	.0000000
ASF	=	.0000000	VOL = .0000000	AFR =	.0000000

SUBT15

WT	=	171652.6			
XCG	=	2011.632	YCG = .0000000	ZCG =	101.1674
IXX	=	685397.1	IYY = 3011571.	IZZ =	2920695.
IXY	=	.0000000	IXZ = 248218.5	IYZ =	.0000000
ASF	=	.0000000	VOL = .0000000	AFR =	.0000000

FUELSY

WT	=	8388.600			
XCG	=	2100.257	YCG = .0000000	ZCG =	142.7000
IXX	=	.0000000	IYY = .0000000	IZZ =	.0000000
IXY	=	.0000000	IXZ = .6906888-02	IYZ =	.0000000
ASF	=	.0000000	VOL = .0000000	AFR =	.0000000

SUBT16

WT	=	180041.2			
XCG	=	2015.761	YCG = .0000000	ZCG =	103.1025
IXX	=	688374.8	IYY = 3028107.	IZZ =	2934253.
IXY	=	.0000000	IXZ = 254572.4	IYZ =	.0000000
ASF	=	.0000000	VOL = .0000000	AFR =	.0000000

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OXIDSY
WT  =  12419.02
XCG =  2032.960        YCG =  .0000000        ZCG =  142.7000
IXX = -.8633610-03     IYY =  .2210204        IZZ =  .0000000
IXY =  .0000000        IXZ = -.6906888-02     IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT17
WT  =  192460.2
XCG =  2016.871        YCG =  .0000000        ZCG =  105.6576
IXX =  692306.5        IYY =  3032782.        IZZ =  2934996.
IXY =  .0000000        IXZ =  256280.4        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SEPSYS
WT  =  2488.139
XCG =  1349.380        YCG =  .0000000        ZCG =  63.50000
IXX = -.5396006-04     IYY =  .0000000        IZZ =  .0000000
IXY =  .0000000        IXZ =  .0000000        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT18
WT  =  194948.3
XCG =  2008.351        YCG =  .0000000        ZCG =  105.1196
IXX =  693248.8        IYY =  3269942.        IZZ =  3171215.
IXY =  .0000000        IXZ =  271199.7        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

CHUTSY
WT  =  5724.150
XCG =  1441.540        YCG =  .0000000        ZCG =  63.50000
IXX =  .0000000        IYY =  .0000000        IZZ = -.5525511-01
IXY =  .0000000        IXZ =  .1726782-02     IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT19
WT  =  200672.5
XCG =  1992.183        YCG =  .0000000        ZCG =  103.9324
IXX =  695327.9        IYY =  3657637.        IZZ =  3556830.
IXY =  .0000000        IXZ =  299514.5        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

FLOTSY
WT  =  103.5436
XCG =  1441.540        YCG =  .0000000        ZCG =  63.50000
IXX = -.1686252-05     IYY =  .8633610-03     IZZ =  .8633610-03
IXY =  .0000000        IXZ =  .2698003-04     IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT20
WT  =  200776.0
XCG =  1991.899        YCG =  .0000000        ZCG =  103.9115
IXX =  695364.4        IYY =  3664448.        IZZ =  3563606.
IXY =  .0000000        IXZ =  300011.7        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000
```

RECADS

WT	=	102.2156			
XCG	=	1411.540	YCG =	.0000000	ZCG = 63.50000
IXX	=	.0000000	IYY =	.0000000	IZZ = .0000000
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT21

WT	=	200878.2			
XCG	=	1991.604	YCG =	.0000000	ZCG = 103.8910
IXX	=	695400.4	IYY =	3671910.	IZZ = 3571029.
IXY	=	.0000000	IXZ =	300528.9	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

FITSUP

WT	=	197.0792			
XCG	=	1555.857	YCG =	.0000000	ZCG = 63.50000
IXX	=	.0000000	IYY =	-.1726722-02	IZZ = -.1726722-02
IXY	=	.0000000	IXZ =	-.5396006-04	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT22

WT	=	201075.3			
XCG	=	1991.177	YCG =	.0000000	ZCG = 103.8514
IXX	=	695469.7	IYY =	3680050.	IZZ = 3579099.
IXY	=	.0000000	IXZ =	301276.7	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

RETRSY

WT	=	3173.528			
XCG	=	2214.257	YCG =	.0000000	ZCG = 63.50000
IXX	=	.0000000	IYY =	-.1105102	IZZ = -.1105102
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT23

WT	=	204248.8			
XCG	=	1994.643	YCG =	.0000000	ZCG = 103.2244
IXX	=	696567.7	IYY =	3714706.	IZZ = 3612658.
IXY	=	.0000000	IXZ =	295206.6	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

RHTSHD

WT	=	4876.489			
XCG	=	2328.257	YCG =	.0000000	ZCG = 63.50000
IXX	=	.0000000	IYY =	.0000000	IZZ = .0000000
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

EPTY24

WT	=	209125.3			
XCG	=	2002.422	YCG =	.0000000	ZCG = 102.2981
IXX	=	698189.9	IYY =	3830747.	IZZ = 3727073.
IXY	=	.0000000	IXZ =	281582.9	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

```
FLBIAS
WT  =  1800.000
XCG =  2010.528        YCG =  .0000000        ZCG =  63.50000
IXX =  .0000000        IYY =  .0000000        IZZ =  .0000000
IXY =  .0000000        IXZ =  .0000000        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT25
WT  =  210925.3
XCG =  2002.492        YCG =  .0000000        ZCG =  101.9670
IXX =  698769.7        IYY =  3831348.        IZZ =  3727097.
IXY =  .0000000        IXZ =  291461.8        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

LOXGAS
WT  =  3870.703
XCG =  1653.737        YCG =  .0000000        ZCG =  63.50000
IXX =  .0000000        IYY = -.5525511-01     IZZ = -.5525511-01
IXY =  .0000000        IXZ =  .8633610-03     IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT26
WT  =  214796.0
XCG =  1996.297        YCG =  .0000000        ZCG =  101.2738
IXX =  699983.7        IYY =  3929510.        IZZ =  3824046.
IXY =  .0000000        IXZ =  292309.9        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

RPGAS
WT  =  3439.784
XCG =  2010.528        YCG =  .0000000        ZCG =  63.50000
IXX =  .0000000        IYY =  .0000000        IZZ =  .0000000
IXY =  .0000000        IXZ =  .0000000        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT27
WT  =  218235.8
XCG =  1996.521        YCG =  .0000000        ZCG =  100.6784
IXX =  701026.3        IYY =  3930698.        IZZ =  3824191.
IXY =  .0000000        IXZ =  291917.1        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

FROST
WT  =  433.5114
XCG =  1807.739        YCG =  .0000000        ZCG =  63.50000
IXX =  .6745008-05     IYY =  .0000000        IZZ = -.6906888-02
IXY =  .0000000        IXZ =  .0000000        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT28
WT  =  218669.3
XCG =  1996.147        YCG =  .0000000        ZCG =  100.6047
IXX =  701155.4        IYY =  3934156.        IZZ =  3827522.
IXY =  .0000000        IXZ =  292572.7        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000
```

TRAPRP

WT	=	12957.93			
XCG	=	2043.099	YCG =	.0000000	ZCG = 63.50000
IXX	=	.0000000	IYY =	.0000000	IZZ = .0000000
IXY	=	.0000000	IXZ =	.0000000	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT29

WT	=	231627.2			
XCG	=	1998.774	YCG =	.0000000	ZCG = 98.52899
IXX	=	704790.6	IYY =	3943609.	IZZ = 3833339.
IXY	=	.0000000	IXZ =	287972.9	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

TRPLOX

WT	=	18073.13			
XCG	=	1818.776	YCG =	.0000000	ZCG = 63.50000
IXX	=	.4316805-03	IYY =	.0000000	IZZ = .0000000
IXY	=	.0000000	IXZ =	.3453444-02	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT30

WT	=	249700.4			
XCG	=	1985.745	YCG =	.0000000	ZCG = 95.99361
IXX	=	709230.7	IYY =	4065287.	IZZ = 3950579.
IXY	=	.0000000	IXZ =	310788.5	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

RPLOSS

WT	=	2084.150			
XCG	=	2010.528	YCG =	.0000000	ZCG = 63.50000
IXX	=	.5396006-04	IYY =	.0000000	IZZ = .2762755-01
IXY	=	.0000000	IXZ =	-.4316805-03	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

SUBT31

WT	=	251784.5			
XCG	=	1985.951	YCG =	.0000000	ZCG = 95.72465
IXX	=	709701.7	IYY =	4066033.	IZZ = 3950851.
IXY	=	.0000000	IXZ =	310423.3	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

LOWLOS

WT	=	2228.614			
XCG	=	1658.737	YCG =	.0000000	ZCG = 63.50000
IXX	=	.5396006-04	IYY =	.0000000	IZZ = .0000000
IXY	=	.0000000	IXZ =	.4316805-03	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

INRT32

WT	=	254013.1			
XCG	=	1983.080	YCG =	.0000000	ZCG = 95.44192
IXX	=	710196.8	IYY =	4117582.	IZZ = 4001905.
IXY	=	.0000000	IXZ =	315456.7	IYZ = .0000000
ASF	=	.0000000	VOL =	.0000000	AFR = .0000000

```
PP
WT  =  766288.1
XCG =  2010.528          YCG =  .0000000          ZCG =  63.50000
IXX =  .0000000          IYY = -14.14531          IZZ = -14.14531
IXY =  .0000000          IXZ =  .0000000          IYZ =  .0000000
ASF =  .0000000          VOL =  .0000000          AFR =  .0000000

SUBT33
WT  =  1020301.
XCG =  2003.694          YCG =  .0000000          ZCG =  71.45223
IXX =  752208.9          IYY =  4190604.          IZZ =  4032912.
IXY =  .0000000          IXZ =  279356.1          IYZ =  .0000000
ASF =  .0000000          VOL =  .0000000          AFR =  .0000000

LOX
WT  =  1739474.
XCG =  1658.737          YCG =  .0000000          ZCG =  63.50000
IXX = -.2762755-01       IYY =  .0000000          IZZ =  .0000000
IXY =  .0000000          IXZ = -.4420408          IYZ =  .0000000
ASF =  .0000000          VOL =  .0000000          AFR =  .0000000

BLOW34
WT  =  2759775.
XCG =  1786.269          YCG =  .0000000          ZCG =  66.43997
IXX =  760986.6          IYY =  .2071654+08       IZZ =  .2055008+08
IXY =  .0000000          IXZ =  660120.8          IYZ =  .0000000
ASF =  .0000000          VOL =  .0000000          AFR =  .0000000
```

MISSION MASS PROPERTIES - LIFTOFF

OB-L/O
WT = 287254.0
XCG = 1135.900 YCG = .6000000 ZCG = 380.7000
IXX = 849089.5 IYY = 6261866. IZZ = 6497481.
IXY = -6587.000 IXZ = 257323.7 IYZ = -2174.700
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT 1
WT = 287254.0
XCG = 1135.900 YCG = .6000000 ZCG = 380.7000
IXX = 849089.5 IYY = 6261866. IZZ = 6497481.
IXY = -6587.000 IXZ = 257323.7 IYZ = -2174.700
ASF = .0000000 VOL = .0000000 AFR = .0000000

ET-L/O
WT = 1805487.
XCG = 160.1446 YCG = .0000000 ZCG = 64.28624
IXX = 354339.6 IYY = .4106551+08 IZZ = .4102286+08
IXY = .0000000 IXZ = 279868.6 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

SUBT 2
WT = 2092741.
XCG = 294.0788 YCG = .8235725-01 ZCG = 107.7178
IXX = 6558802. IYY = .1044110+09 IZZ = .9924868+08
IXY = 24729.24 IXZ = .1705201+08 IYZ = 7980.396
ASF = .0000000 VOL = .0000000 AFR = .0000000

LB-L/O
WT = 2759775.
XCG = 1786.269 YCG = .0000000 ZCG = 66.43997
IXX = 760986.6 IYY = .2071648+08 IZZ = .2055002+08
IXY = .0000000 IXZ = 660119.0 IYZ = .0000000
ASF = .0000000 VOL = .0000000 AFR = .0000000

LNCH 3
WT = 4852516.
XCG = 1142.733 YCG = .3551815-01 ZCG = 84.24185
IXX = 7757503. IYY = .6975747+09 IZZ = .6918082+09
IXY = -6841.208 IXZ = 1888855. IYZ = 8853.716
ASF = .0000000 VOL = .0000000 AFR = .0000000

MISSION MASS PROPERTIES - PRIOR-BECO

```
OB-PSP
WT  =  287254.0
XCG =  1135.900        YCG =  .6000000        ZCG =  380.7000
IXX =  849089.5        IYY =  6261806.        IZZ =  6497481.
IXY = -6587.000        IXZ =  257323.7        IYZ = -2174.700
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT 1
WT  =  287254.0
XCG =  1135.900        YCG =  .6000000        ZCG =  380.7000
IXX =  849089.5        IYY =  6261866.        IZZ =  6497481.
IXY = -6587.000        IXZ =  257323.7        IYZ = -2174.700
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

ET-PSP
WT  =  1334240.
XCG =  292.6766        YCG =  .0000000        ZCG =  64.56393
IXX =  354254.5        IYY =  .1510934+08     IZZ =  .1506678+08
IXY =  .0000000        IXZ =  239261.5        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT 2
WT  =  1621494.
XCG =  442.0569        YCG =  .1062923        ZCG =  120.5687
IXX =  6302130.        IYY =  .6274456+08     IZZ =  .5783886+08
IXY =  19224.37        IXZ =  .1409643+08     IYZ =  7502.338
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

LB-PSP
WT  =  254013.1
XCG =  1983.080        YCG =  .0000000        ZCG =  95.44192
IXX =  710196.8        IYY =  4117582.        IZZ =  4001902.
IXY =  .0000000        IXZ =  315456.6        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

PRSP 3
WT  =  1875507.
XCG =  650.7685        YCG =  .9189642-01     ZCG =  117.1656
IXX =  7042254.        IYY =  .1794571+09     IZZ =  .1744058+09
IXY =  11460.18        IXZ =  .1257648+08     IYZ =  7628.935
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000
```

MISSION MASS PROPERTIES - POST-BECO

```
OB-ASP
WT  =  287254.0
XCG =  1135.900        YCG =  .6000000        ZCG =  380.7000
IXX =  849089.5        IYY =  6261866.        IZZ =  6497481.
IXY = -6587.000        IXZ =  257323.7        IYZ = -2174.700
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT 1
WT  =  287254.0
XCG =  1135.900        YCG =  .6000000        ZCG =  380.7000
IXX =  849089.5        IYY =  6261866.        IZZ =  6497481.
IXY = -6587.000        IXZ =  257323.7        IYZ = -2174.700
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

ET-ASP
WT  =  1334240.
XCG =  292.6766        YCG =  .0000000        ZCG =  64.56393
IXX =  354254.5        IYY =  .1510934+08     IZZ =  .1506678+08
IXY =  .0000000        IXZ =  239261.5        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

AFSP 2
WT  =  1621494.
XCG =  442.0569        YCG =  .1062923        ZCG =  120.5687
IXX =  6302130.        IYY =  .6274456+08     IZZ =  .5783886+08
IXY =  19224.37        IXZ =  .1409643+08     IYZ =  7502.338
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000
```

MISSION MASS PROPERTIES - MECO

```
OB-MCO
WT  =  287254.0
XCG =  1135.900        YCG =  .6000000        ZCG =  380.7000
IXX =  849089.5        IYY =  6261866.        IZZ =  6497481.
IXY = -6587.000        IXZ =  257323.7        IYZ = -2174.700
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

SUBT 1
WT  =  287254.0
XCG =  1135.900        YCG =  .6000000        ZCG =  380.7000
IXX =  849089.5        IYY =  6261866.        IZZ =  6497481.
IXY = -6587.000        IXZ =  257323.7        IYZ = -2174.700
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

ET-MCO
WT  =  98039.20
XCG =  639.6530        YCG =  .0000000        ZCG =  77.97937
IXX =  350144.1        IYY =  5061767.        IZZ =  5023308.
IXY =  .0000000        IXZ =  132949.7        IYZ =  .0000000
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000

MECO 2
WT  =  385293.2
XCG =  1009.628        YCG =  .4473279        ZCG =  303.6717
IXX =  2644982.        IYY =  .1665448+08     IZZ =  .1540590+08
IXY = -1889.615        IXZ =  2760265.        IYZ =  690.7987
ASF =  .0000000        VOL =  .0000000        AFR =  .0000000
```

SIGMA CORPORATION

EDIN0502A DESIGN

SIMULATION RESULTS

```
FORECASTER: EDIN DESIGN CENTER                          DATE: 10 OCT 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC          TIME: 17:07
STUDY NO: EDIN0502
```

CONCEPT: A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 7.00 HIGH PRESSURE ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR REPLACEMENT OF THE SOLID ROCKET BOOSTERS.

MISSION: MAXIMUM PAYLOAD
DUE EAST LAUNCH FROM ETR
A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL MILE REFERENCE ORBIT.
A 100 FPS RCS TRANSLATION DELTA VEL.

TRAJECTORY: DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH PROFILE AND INITIAL TILT RATE.
- MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS/ADA
- END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO

ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY HIGH PRESSURE ENGINE THROTTLING AND/OR OMS THROTTLING.
- MAX DYNAMIC PRESSURE = 650.0 PSF
- MAX ACCELERATION = 3.0 G

PROPULSION: LRB: 7.00 HIGH PRESSURE ENGINES RATED AS FOLLOWS:
- THRUST(SL) = 680000.00 LBS
- THRUST(VAC) = 735300.00 LBS
- THROTTLE = 1.00 TO .500
- ISP(SL) = 319.60 SEC.
- ISP(VAC) = 345.60 SEC.
- FLOWRATE = 2127.7 LB/SEC
- EXIT AREA = 27.122 SQ FT
- MIX RATIO = 2.40:1

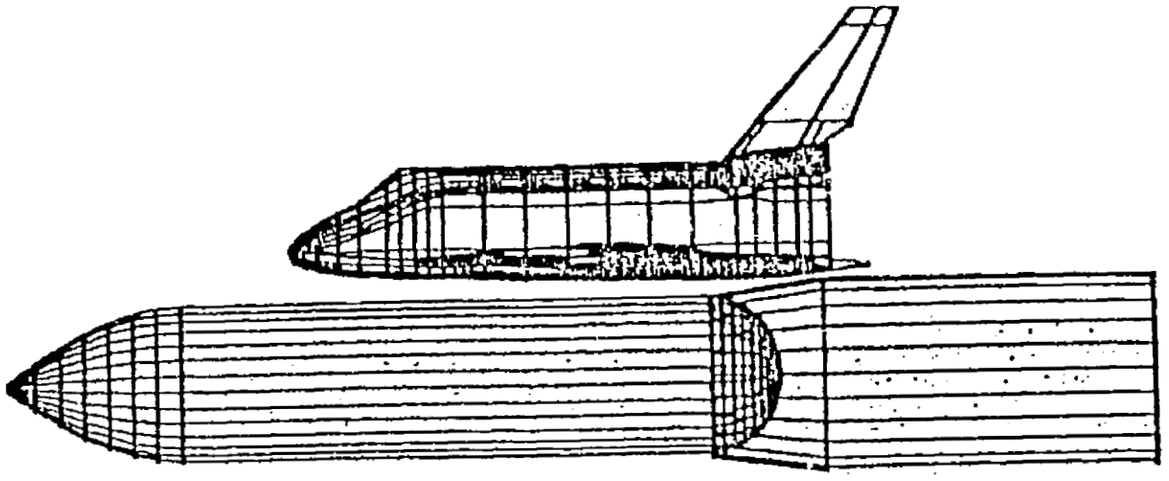
ORBITER: THREE OMS ENGINES RATED AS FOLLOWS:
- THRUST(SL) = 375000.00 LBS
- THRUST(VAC) = 470000.00 LBS
- THROTTLE = 1.09 TO .500
- ISP(SL) = 363.20 SEC
- ISP(VAC) = 455.20 SEC
- FLOWRATE = 1032.5 LB/SEC
- EXIT AREA = 44.896 SQ FT
- MIX RATIO = 6.00:1

AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
- REF AREA = 2557.0 SQ FT

STRUCTURE: ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND INCREASED UP PAYLOADS.

MASS PROPERTIES: MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC ASSUMPTIONS.
- LRB: WERS BASED ON SATURN TECHNOLOGY.
- ET: FIXED MASS FRACTION DISTRIBUTED IN ACCORDANCE WITH SHUTTLE ET WEIGHT STATEMENT.
- ORBITER: FEB 1975 SHUTTLE WITH MODS FOR INCREASED UP PAYLOAD.

EDIN0502A DESIGN SIMULATION RESULTS.



WEIGHTS SUMMARY REPORT

GLOW		4817348.62
ET LIFT-OFF WEIGHT		1805487.20
ET INERT WEIGHT	98039.26	
ET PROPELLANT	1707487.61	
LRB LIFT-OFF WEIGHT		2692607.59
LRB INERT WEIGHT	234010.25	
LRB PROPELLANT	2458597.34	
ORBITER LIFT-OFF WEIGHT		319254.00
ORBITER INERT WEIGHT	187254.00	
PAYLOAD	132000.00	

ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2862.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	19874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	28054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2929.	
ELECTRICAL CONVERSION	6960.	
HYDRAULIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 100K PAYLD	390.	
ORBITER EMPTY WEIGHT		151715.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1840.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16149.	
ORBITER INERT WEIGHT		187254.
PAYLOAD		132000.
ORBITER PRELAUNCH WEIGHT		319254.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		16260.
BHD	79.	
FWD FRAME	51.	
FWD OGIVE	1342.	
AFT OGIVE	4511.	
XT 745 FRAME	313.	
BARREL	2917.	
INTERTANK FRAME	1064.	
AFT DOME	3469.	
SLOSH BAFFLES	2514.	
INTERTANK		12708.
MACHINED BARREL PNLS	5088.	
SK/STGR BARREL PNLS	5500.	
STABILIZING FRAMES(4)	1505.	
SRB THRST XT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	68.	
BARREL PNLS SPLICES (8)	113.	
FRAME STABLIZERS	244.	
ET ASSY FASTENERS	191.	

LH2 TANK		
FWD DOME		2[illegible].
AT 1128.9 FRAME	1908.	
BARREL NO.4	1877.	
AT 1377 FRAME	[illegible].	
BARREL NO.3	[illegible].	
AT 1624 FRAME	[illegible].	
BARREL NO.2	[illegible].	
AT 1871 FRAME	[illegible].	
BARREL NO.1	[illegible].	
AT 2093 FRAME	[illegible].	
AFT DOME	[illegible].	
THERMAL PROTECTION	[illegible].	
LOX TANK		7789.
INTERTANK	1457.	
LH2 TANK	1780.	
PROP (MECH+ELEC)	4027.	
PROPULSION AND MECHANICAL SYSTEMS	314.	
LOX FEED SYS		4864.
LOX ANTIGEYSER SYS	1906.	
LOX VENT SYS	131.	
LOX PRESS. SYS	101.	
LH2 FEED SYS	317.	
LH2 RECIR. SYS	581.	
LH2 VENT SYS	56.	
LH2 PRESS. SYS	153.	
HELIUM INJ. SYS	168.	
INTERTANK PURGE SYS	65.	
HAZARD GAS DETECTION SYS	96.	
FAIRINGS AND CONDUIT	10.	
LINE SUPTS. AND ATTACHS.	407.	
ELECTRICAL SYSTEM	637.	
ET WIRING ASSY		875.
ORB WIRING ASSY	138.	
INSTRUMENTATION	0.	
CABLING ATTACHS.+SENSOR SUPTS.	17.	
ORB/ORB ATTACHMENTS	73.	
ORBITER SUPPORTS		5388.
UMBILICAL BEAM	3677.	
ORB/ET ATTACH PTGS	754.	
ORB/ET ATTACH PTGS	880.	
ET/ORB UMBILICAL HDWR	0.	
MANUFACTURING VARIATION WT.	547.	
EMPTY WEIGHT		506.
UNUSABLE FLUIDS		97810.
LH2 IN TANK		496.
LH2 IN LINE	873.	
LOX IN LINE	56.	
PRE-PRESS.+INFLIGHT GASES	167.	
GH2		4408.
GOX	1145.	
HELIUM	1263.	
SEPARATION HARDWARE	37.	
ORB SUPPORTS		6.
ORB FITTINGS	0.	
ET REAR PES	6.	
ET INERT WT		9818.
MAIN PROPELLANTS		98032.
LOX		1707448.
LH2	1421627.	
ET LIFT-OFF WEIGHT	843821.	
FILL FRACTION		1805477.
		.[illegible]

LIQUID ROCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		93058.
INTEGRAL LOX TANK	20679.	
INTEGRAL FUEL TANK	14022.	
INTERSTAGE	8583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	33615.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		2189.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1248.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		799.
ELECTRICAL SYSTEM	684.	
CONTROL SYSTEM	115.	
INSTRUMENTATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		68208.
ENGINES (DRY)	37345.	
ACCESSORIES	416.	
GIMBAL SYSTEM	5283.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	8389.	
OXIDIZER SYSTEM	12419.	
SEPARATION AND RECOVERY SYSTEM		16665.
SEPARATION SYSTEM	2480.	
CHUTE SYS (MAIN AND DROGUE)	5724.	
FLOATATION SYSTEM	104.	
RECOVERY AIDS	102.	
FITTINGS AND SUPPORTS	197.	
RETRO SYS (100 F/S DEL V)	3174.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		189356.
CONTINGENCY		0.
EMPTY WEIGHT		189356.
PROPELLANT RESIDUALS		40383.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	3871.	
TRAPPED FUEL TANK GASES	3440.	
FROST TRAPPED	434.	
TRAPPED FUEL	12160.	
TRAPPED LOX	18073.	
IN-FLIGHT LOSSES		4271.
FUEL LOSSES	1956.	
LOX LOSSES	2229.	
MAIN PROPELLANTS		2458598.
FUEL	719124.	
LOX	1739474.	
BLOW		2692608.
MASS FRACTION (BASED ON INERT WT)		.9131

ORBITER WT	319254.0
ET WEIGHT	1805487.2
LRB STAGE WT	2692607.6
GLOW	4817348.7
EFFECTIVE STG 1 LAMBDA	.92816
EFFECTIVE STG 2 LAMBDA	.92097

```
CONVERGENCE DATA:
      GLOW                                          4817349.
         THROW WEIGHT                                          417338.
         PAYLOAD                                               132044.
      TOTAL VIDEAL                                   30307.8
         STAGE 1 VIDEAL                                        10997.9
         STAGE 2 VIDEAL                                        19309.9
      TOTAL PROPELLANT                              4166001.
         LRB PROPELLANT                                       2458513.
         ET PROPELLANT                                        1707488.

STAGE 1 SIZING DATA
      AVERAGE SP. IMP.                                346.03
      LIFT-OFF T/W                                     1.236
      MAXIMUM Q                                        509.9
      TIME AT MAX Q                                     80.0
      STG 1 MAX LF                                      3.00
      TIME AT MAX LF                                   159.0
      EFF WDOT/LRB                                   14692.6
      EFF WDOT/EVENT 1                               18068.9

STAGING CONDITIONS:
      WEIGHT                                        1793884.
      REL VELOCITY (FPS)                              6414.5
      REL F.P. ANGLE (DEG)                             24.97
      ALTITUDE (FT)                                  207760.
      TIME (SEC)                                       167.33
      ATT AFTER STG (DEG)                                1.13
```

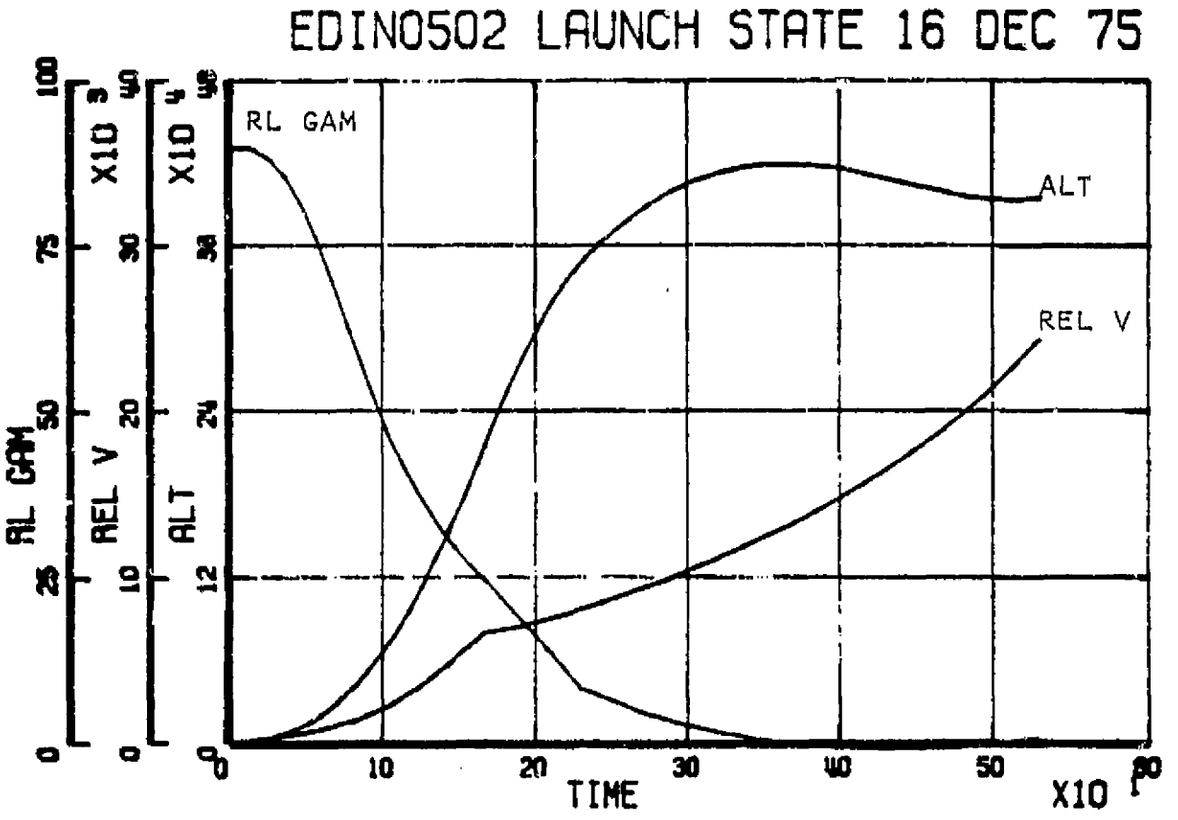
****

MISSION SUMMARY: OCTOBER 10, 1975

PARAMETER	EVENT 1	EVENT 2	EVENT 3	EVENT 4
TIME (SEC)	167.3	236.5	531.0	606.0
ALTITUDE (K FT)	207.8	348.6	394.4	0
REL VELOCITY (100 FPS)	64.1	81.4	243.0	201.3
REL GAMMA (DEG)	25.0	8.27	.528	-89.8
WEIGHT (K LBS)	4817.3	1559.9	1326.4	234.0
WEIGHT DROP (K LBS)	234.0	0	0	0
THROW WEIGHT (K LBS)	1559.9	1326.4	417.34	0
CUM VIDEAL (100 FPS)	110.0	133.7	303.1	0
DOWNRANGE (NMI)	45.1	132.7	912.0	286.2

EVENT 1 BECO/SEPARATION EVENT 3 MECO/INJECTION
EVENT 2 RTLS/ROA CONSTRAINT EVENT 4 LRB TOUCHDOWN

****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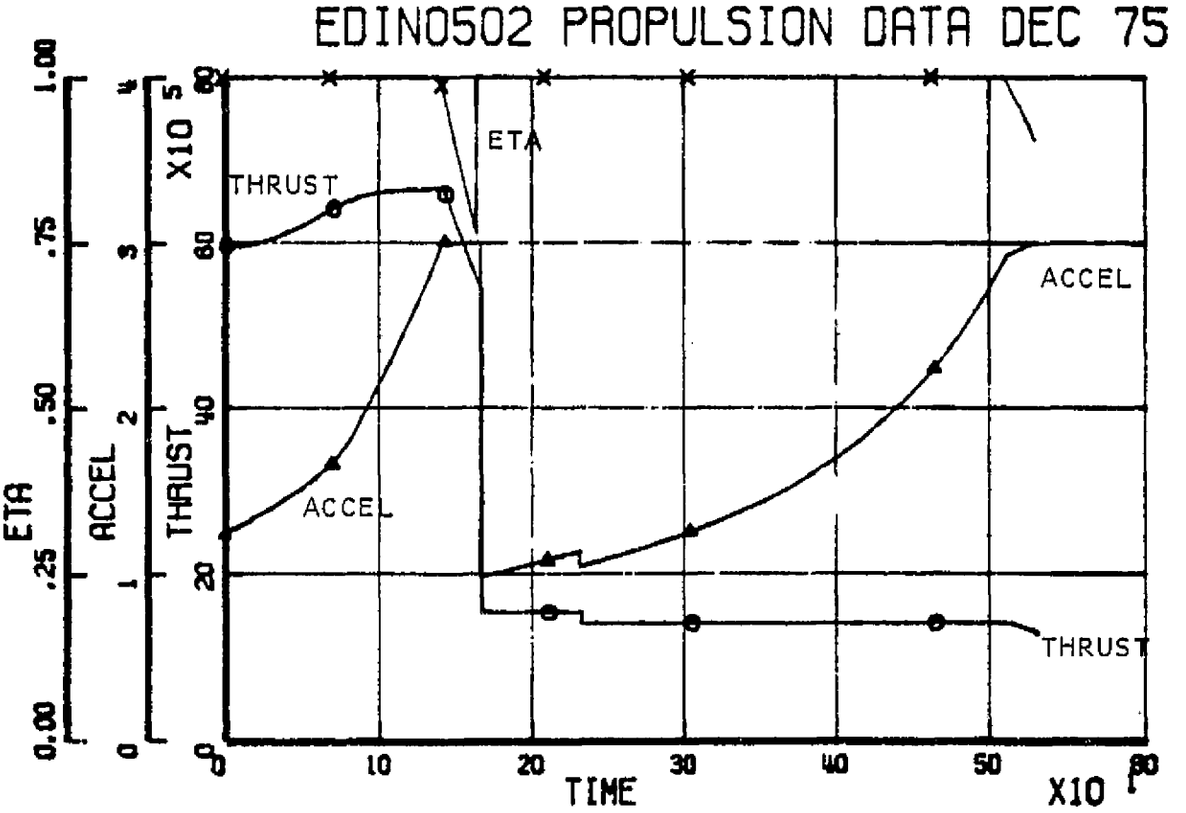
ALT
REL V
RL GAM
REL V
ALT
X10 3
X10 4
TIME
X10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ACCEL
THRUST
ETA
ACCEL
THRUST
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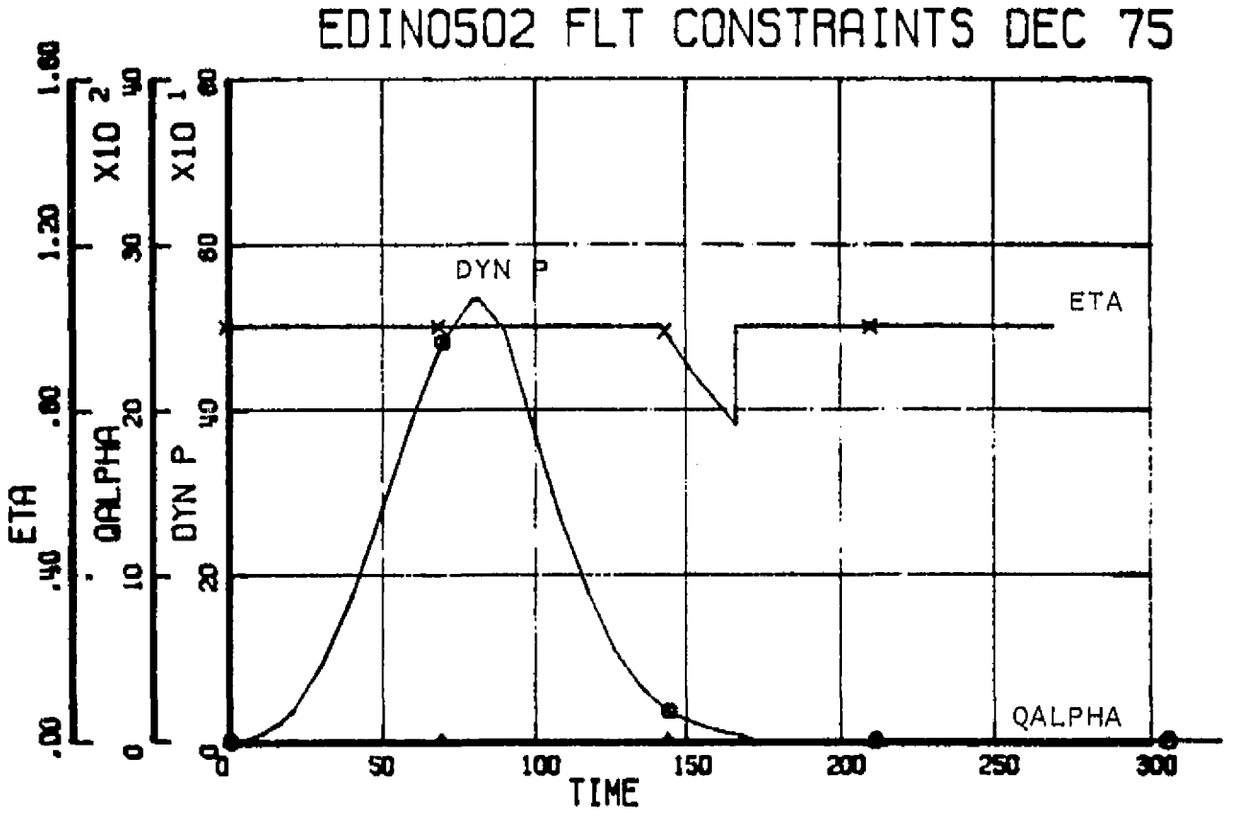
TIME
X10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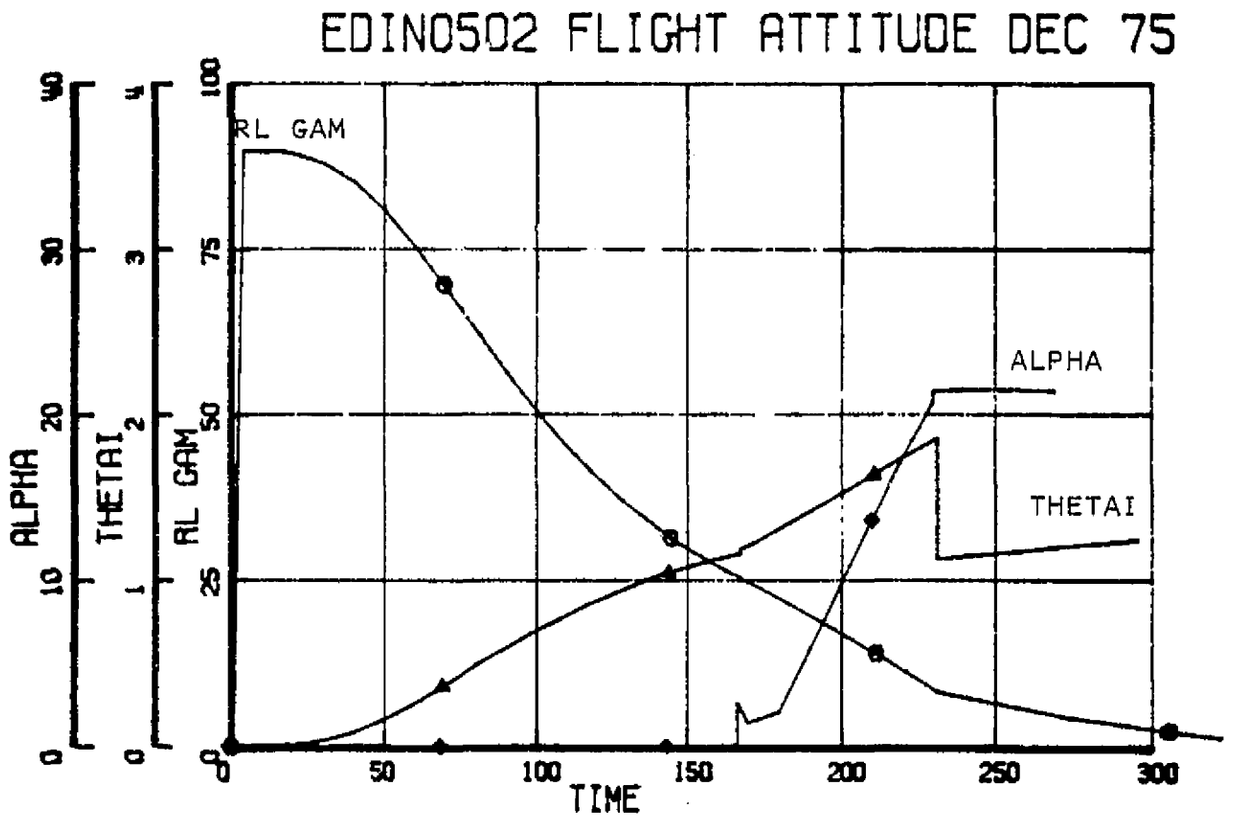
ETA
QALPHA X10 2
DYN P X10 1
DYN P
ETA
QALPHA
TIME
0
50
100
150
200
250
300
.00
.40
.80
1.20
1.60
10
20
30
40
60
80
90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ALPHA
THETAI
RL GAM
RL GAM
ALPHA
THETAI
TIME
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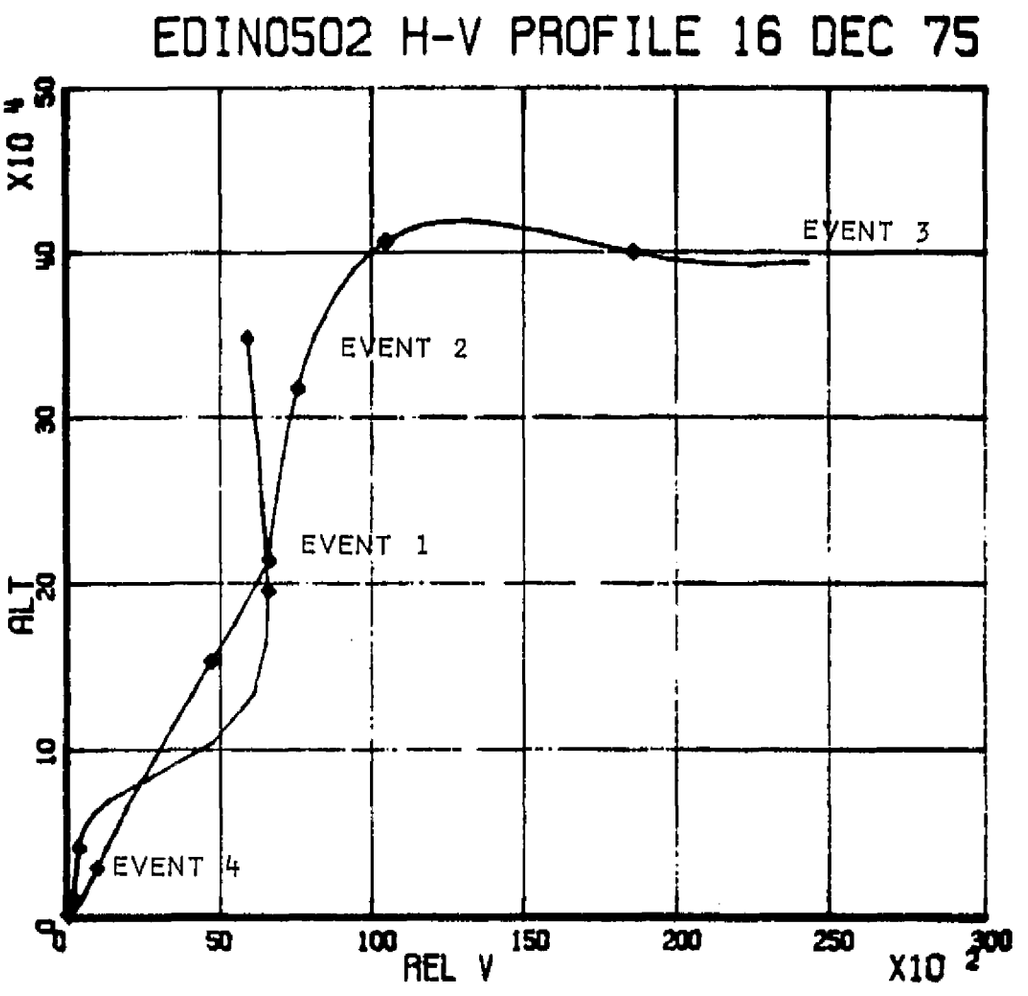
150
200
250
300
10
20
30
50
75
90
100
1
2
3
4


EDIN0502 H-V PROFILE 16 DEC 75
X10 4
ALT
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10
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30
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50
EVENT 1
EVENT 2
EVENT 3
EVENT 4
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50
100
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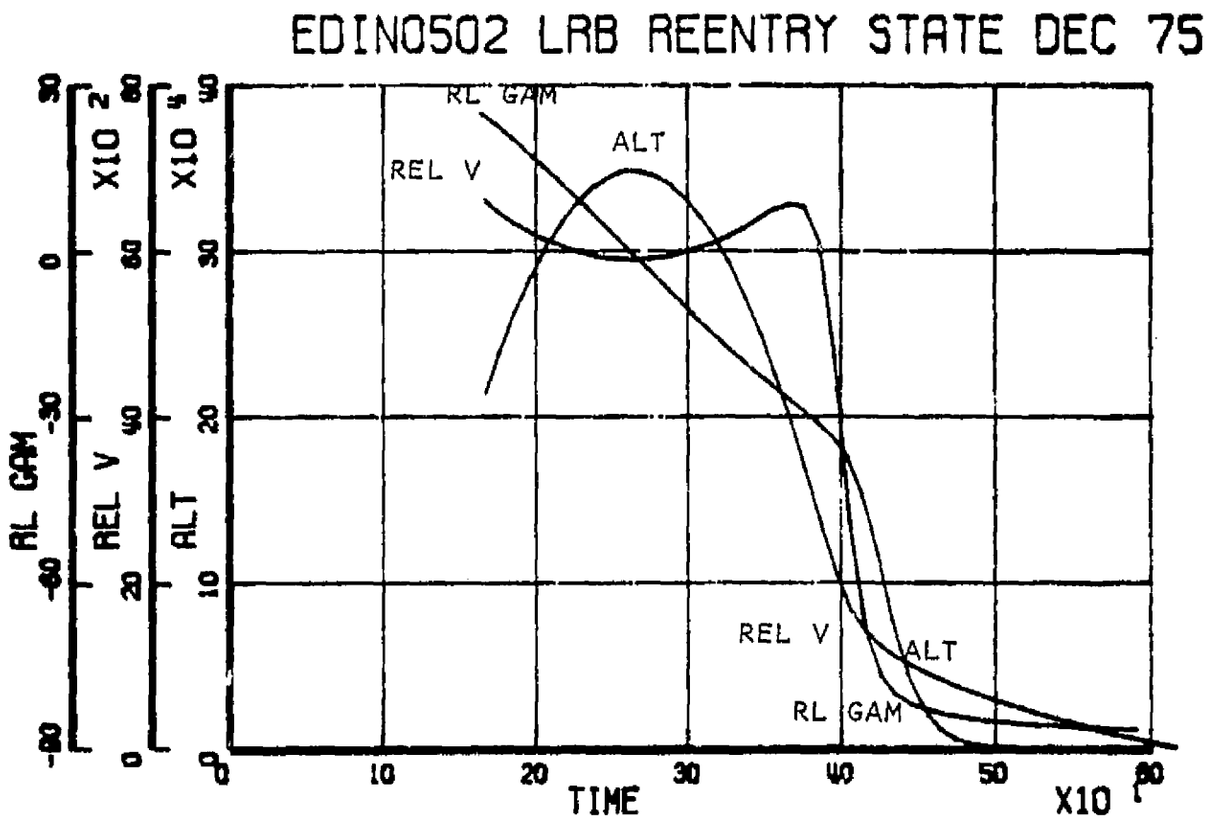
300
REL V
X10 2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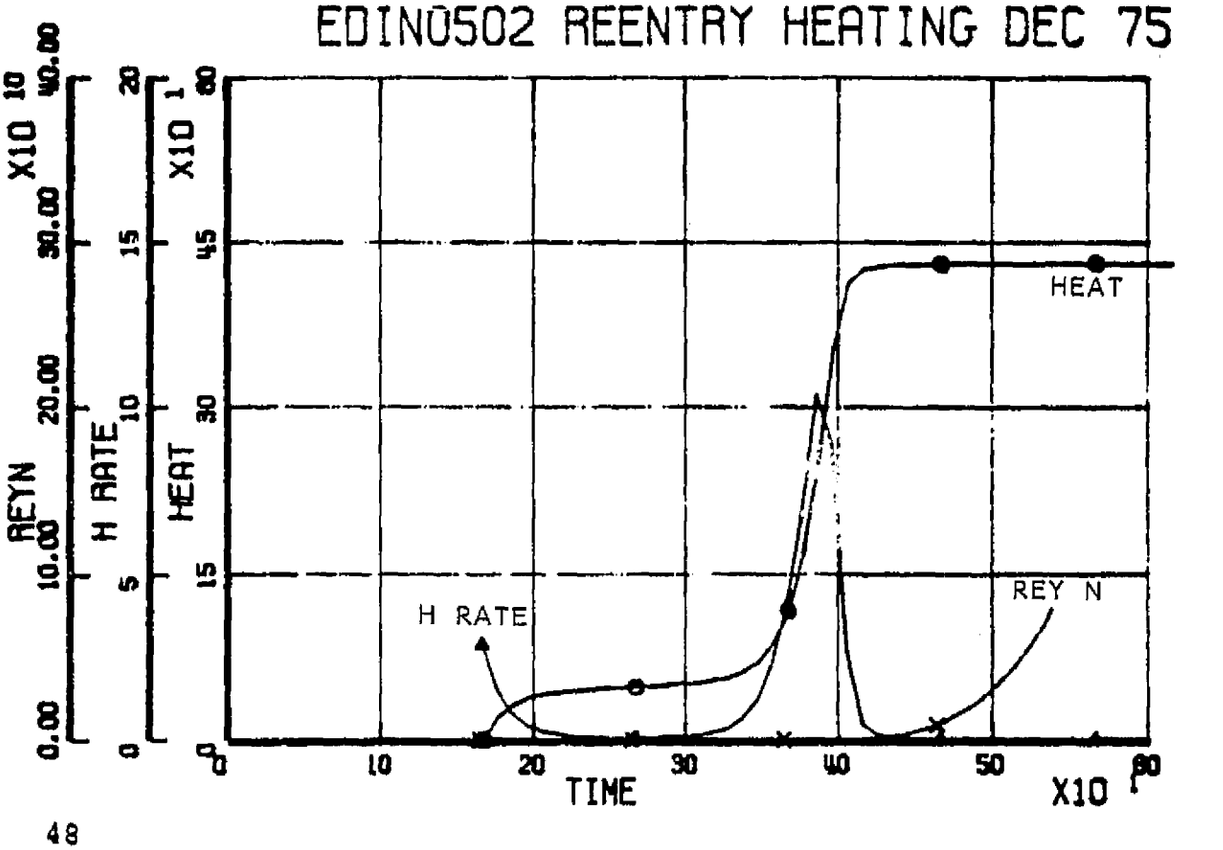
ALT
REL V
REL V
ALT
RL GAM
RL GAM
REL V
ALT
TIME
X10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HEAT
H RATE
REY N
REYN
H RATE
HEAT
TIME
X10

SIGMA CORPORATION

EDIN0502B DESIGN

SIMULATION RESULTS

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FORECASTER: EDIN DESIGN CENTER                          DATE: 10 OCT 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC          TIME: 17:07
STUDY NO: EDIN0502
```

CONCEPT: A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 7.00 HIGH PRESSURE ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR REPLACEMENT OF THE SOLID ROCKET BOOSTERS.

MISSION: MAXIMUM PAYLOAD
DUE EAST LAUNCH FROM ETR
A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL MILE REFERENCE ORBIT.
A 100 FPS RCS TRANSLATION DELTA VEL.

TRAJECTORY: DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH PROFILE AND INITIAL TILT RATE.
- MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS/ROA
- END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO

ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY HIGH PRESSURE ENGINE THROTTLING AND/OR SSME THROTTLING.
- MAX DYNAMIC PRESSURE = 650.0 PSF
- MAX ACCELERATION = 3.0 G

PROPULSION: LRB: 7.00 HIGH PRESSURE ENGINES RATED AS FOLLOWS:
- THRUST(SL) = 680000.00 LBS
- THRUST(VAC) = 735300.00 LBS
- THROTTLE = 1.00 TO .500
- ISP(SL) = 319.60 SEC.
- ISP(VAC) = 345.60 SEC.
- FLOWRATE = 2127.7 LB/SEC
- EXIT AREA = 27.122 SQ FT
- MIX RATIO = 2.40:1

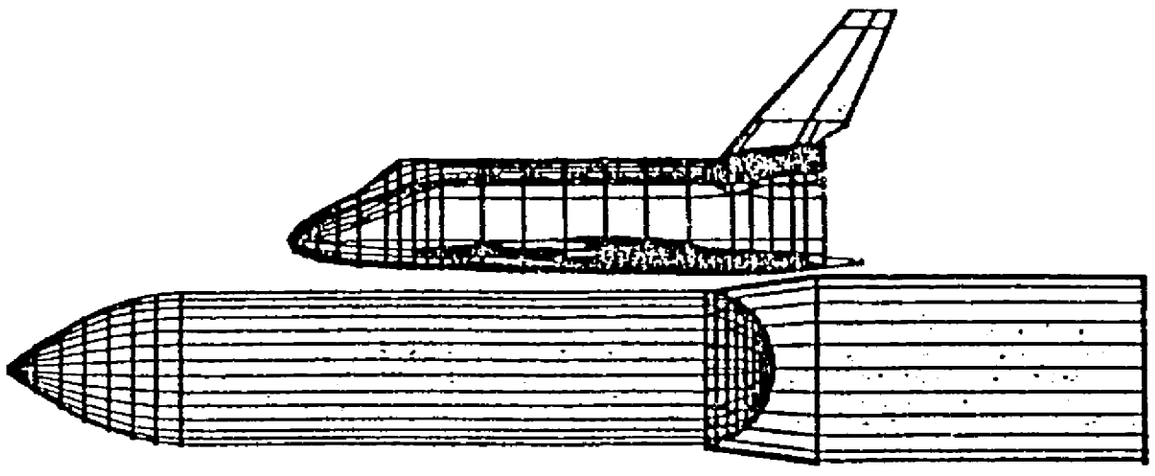
ORBITER: THREE SSME ENGINES RATED AS FOLLOWS:
- THRUST(SL) = 375000.00 LBS
- THRUST(VAC) = 470000.00 LBS
- THROTTLE = 1.09 TO .500
- ISP(SL) = 363.20 SEC
- ISP(VAC) = 455.20 SEC
- FLOWRATE = 1032.5 LB/SEC
- EXIT AREA = 44.896 SQ FT
- MIX RATIO = 6.00:1

AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
- REF AREA = 2557.0 SQ FT

STRUCTURE: ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND INCREASED UP PAYLOADS.

MASS PROPERTIES: MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC ASSUMPTIONS.
- LRB: WERE BASED ON SATURN TECHNOLOGY.
- ET: FIXED MASS FRACTION DISTRIBUTED IN ACCORDANCE WITH SHUTTLE ET WEIGHT STATEMENT.
- ORBITER: FEB 1975 SHUTTLE WITH MODS FOR INCREASED UP PAYLOAD.

EDIN0502B DESIGN SIMULATION RESULTS.



WEIGHTS SUMMARY REPORT

GLOW		4927992.12
ET LIFT-OFF WEIGHT		1911240.42
ET INERT WEIGHT	104144.4	
ET PROPELLANT	1807098.00	
LRB LIFT-OFF WEIGHT		2692607.81
LRB INERT WEIGHT	234010.25	
LRB PROPELLANT	2458597.56	
ORBITER LIFT-OFF WEIGHT		324144.00
ORBITER INERT WEIGHT	187254.00	
PAYLOAD	136881.36	

ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2862.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	19874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	28054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2929.	
ELECTRICAL CONVERSION	6960.	
HYDRAULIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 100K PAYLD	390.	
ORBITER EMPTY WEIGHT		151715.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1840.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16149.	
ORBITER INERT WEIGHT		187254.
PAYLOAD		136890.
ORBITER PRELAUNCH WEIGHT		324144.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		17208.
BHD	84.	
FWD FRAME	54.	
FWD OGIVE	1420.	
AFT OGIVE	4774.	
XT 745 FRAME	331.	
BARREL	3087.	
INTERTANK FRAME	1126.	
AFT DOME	3671.	
SLOSH BAFFLES	2660.	
INTERTANK		13449.
MACHINED BARREL PNLS	5385.	
SK/STGR BARREL PNLS	5821.	
STABILIZING FRAMES(4)	1593.	
SRB THRST XT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	72.	
BARREL PNLS SPLICES (8)	119.	
FRAME STABLIZERS	258.	
ET ASSY FASTENERS	202.	

LH2 TANK		42216.
FWD DOME	2013.	
XT 1129.9 FRAME	1987.	
BARREL NO.4	6905.	
XT 1377 FRAME	692.	
BARREL NO.3	6942.	
XT 1624 FRAME	693.	
BARREL NO.2	6946.	
XT 1871 FRAME	2176.	
BARREL NO.1	7347.	
XT 2058 FRAME	4159.	
AFT DOME	2355.	
THERMAL PROTECTION		8180.
LOX TANK	1754.	
INTERTANK	1821.	
LH2 TANK	4273.	
PROP (MECH+ELEC)	333.	
PROPULSION AND MECHANICAL SYSTEMS		4766.
LOX FEED SYS	2038.	
LOX ANTIGEYER SYS	191.	
LOX VENT SYS	107.	
LOX PRESS. SYS	232.	
LH2 FEED SYS	583.	
LH2 RECIR. SYS	38.	
LH2 VENT SYS	162.	
LH2 PRESS. SYS	172.	
HELIUM INJ. SYS	26.	
INTERTANK PURGE SYS	101.	
HAZARD GAS DETECTION SYS	10.	
FAIRINGS AND CONDUIT	431.	
LINE SUPTS. AND ATTACHS.	675.	
ELECTRICAL SYSTEM		295.
ET WIRING ASSY	199.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	18.	
CABLING ATTACHS.+SENSOR SUPTS.	77.	
ORB/SRB ATTACHMENTS		5670.
ORBITER SUPPORTS	3891.	
UMBILICAL BEAM	798.	
ORB/ET ATTACH FTGS	296.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	685.	
MANUFACTURING VARIATION WT.		536.
EMPTY WEIGHT		92321.
UNUSABLE FLUIDS		515.
LH2 IN TANK	289.	
LH2 IN LINE	59.	
LOX IN LINE	166.	
PRE-PRESS.+INFLIGHT GASES		4662.
GH2	1212.	
GOX	3411.	
HELIUM	39.	
SEPARATION HARDWARE		6.
SRB SUPPORTS	0.	
ORB FITTINGS	6.	
FLT PERF RES		6641.
ET INERT WT		104144.
MAIN PROPELLANTS		1807096.
LOX	1548939.	
LH2	258157.	
ET LIFT-OFF WEIGHT		1911240.
MASS FRACTION		.9490

LIQUID ROCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		93058.
INTEGRAL LOX TANK	20679.	
INTEGRAL FUEL TANK	14082.	
INTERSTAGE	8583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	33615.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		2189.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1248.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		799.
ELECTRICAL SYSTEM	684.	
CONTROL SYSTEM	115.	
INSTRUMENTATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		68208.
ENGINES (DRY)	37345.	
ACCESSORIES	416.	
GIMBAL SYSTEM	5283.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	8389.	
OXIDIZER SYSTEM	12419.	
SEPARATION AND RECOVERY SYSTEM		16665.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	5724.	
FLOATATION SYSTEM	104.	
RECOVERY AIDS	102.	
FITTINGS AND SUPPORTS	197.	
RETRO SYS (100 F/S DEL V)	3174.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		189356.
CONTINGENCY		0.
EMPTY WEIGHT		189356.
PROPELLANT RESIDUALS		40383.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	3871.	
TRAPPED FUEL TANK GASES	3440.	
FROST TRAPPED	434.	
TRAPPED FUEL	12160.	
TRAPPED LOX	18073.	
IN-FLIGHT LOSSES		4271.
FUEL LOSSES	1956.	
LOX LOSSES	2229.	
MAIN PROPELLANTS		2458598.
FUEL	719124.	
LOX	1739474.	
BLOW		2692608.
MASS FRACTION (BASED ON INERT WT)		.9131

ORBITER WT	324144.0
ET WEIGHT	1911240.4
LRB STAGE WT	3692607.8
GLOW	4927992.2
EFFECTIVE STG 1 LAMBDA	.92807
EFFECTIVE STG 2 LAMBDA	.92289

```
CONVERGENCE DATA:
       GLOW                                    4928000.
          THROW WEIGHT                                      428280.
          PAYLOAD                                           136881.
       TOTAL VIDEAL                             30515.0
          STAGE 1 VIDEAL                                    10543.7
          STAGE 2 VIDEAL                                    19971.3
       TOTAL PROPELLANT                        4265710.
          LRB PROPELLANT                                   2458612.
          ET PROPELLANT                                    1807098.

STAGE 1 SIZING DATA
       AVERAGE SP. IMP.                          345.50
       LIFT-OFF T/W                               1.209
       MAXIMUM Q                                  487.8
       TIME AT MAX Q                               90.0
       STG 1 MAX LF                                3.00
       TIME AT MAX LF                             166.1
       EFF WDOT/LRB                             14805.6
       EFF WDOT/EVENT 1                         18181.9

STAGING CONDITIONS:
       WEIGHT                                  1908724.
       REL VELOCITY (FPS)                        5989.8
       REL F.P. ANGLE (DEG)                       23.43
       ALTITUDE (FT)                            185554.
       TIME (SEC)                                166.06
       ATT AFTER STG (DEG)                          .99
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ORIGINAL PAGE IS
OF POOR QUALITY

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MISSION SUMMARY: OCTOBER 10, 1975

   PARAMETER            EVENT 1   EVENT 2   EVENT 3   EVENT 4
-------------------------------------------------------------
TIME (SEC)                166.1     257.2     560.9     578.3
ALTITUDE (K FT)           185.6     348.6     394.4         0
REL VELOCITY (100 FPS)     59.9      81.4     243.0     201.3
REL GAMMA (DEG)            23.4      8.27      .529     -89.8
WEIGHT (K LBS)           4928.0    1674.7    1367.0     234.0
WEIGHT DROP (K LBS)       234.0         0         0         0
THROW WEIGHT (K LBS)     1674.7    1367.0    428.28         0
CUM VIDEAL (100 FPS)      105.4     135.2     305.1         0
DOWNRANGE (NMI)            40.9     153.5     954.5     236.9

EVENT 1   BECO/SEPARATION              EVENT 3  MECO/INJECTION
EVENT 2   RTLS/AOA CONSTRAINT          EVENT 4  LRB TOUCHDOWN
```

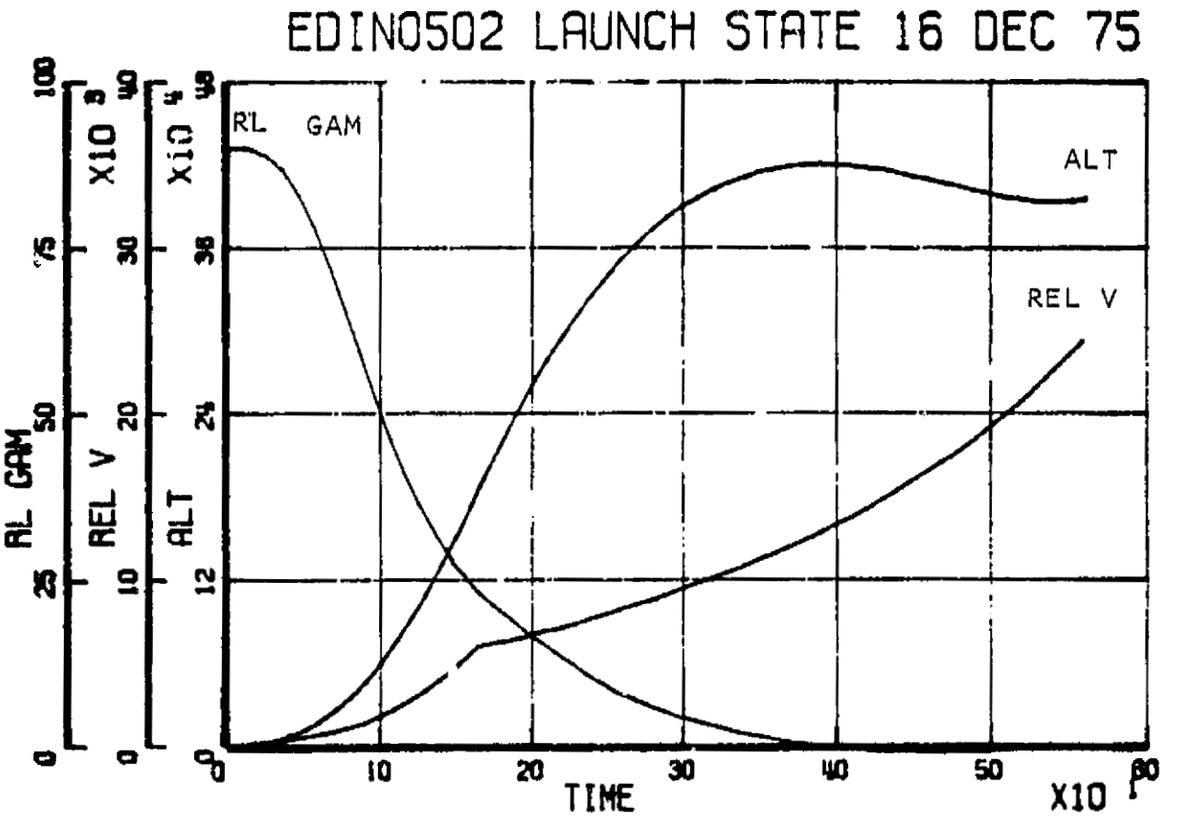
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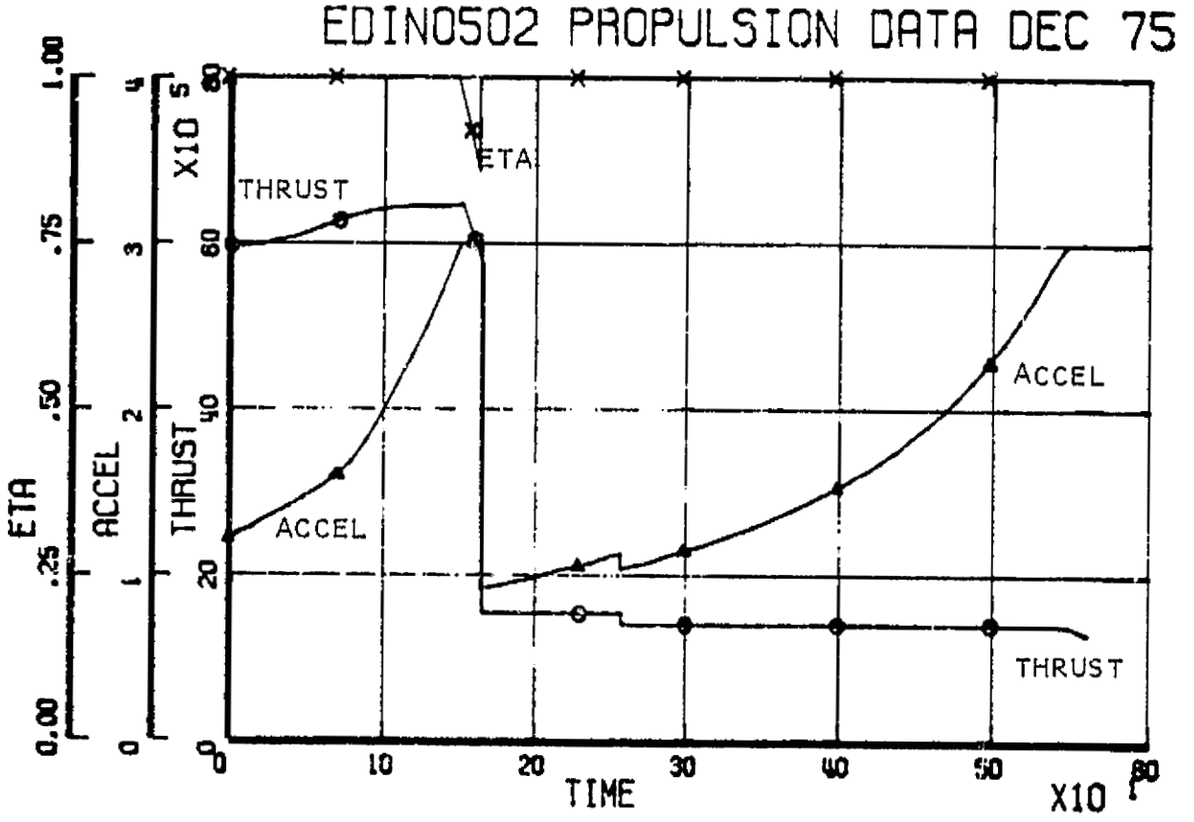
REL V
ALT
X10 3
X10 4
TIME
X10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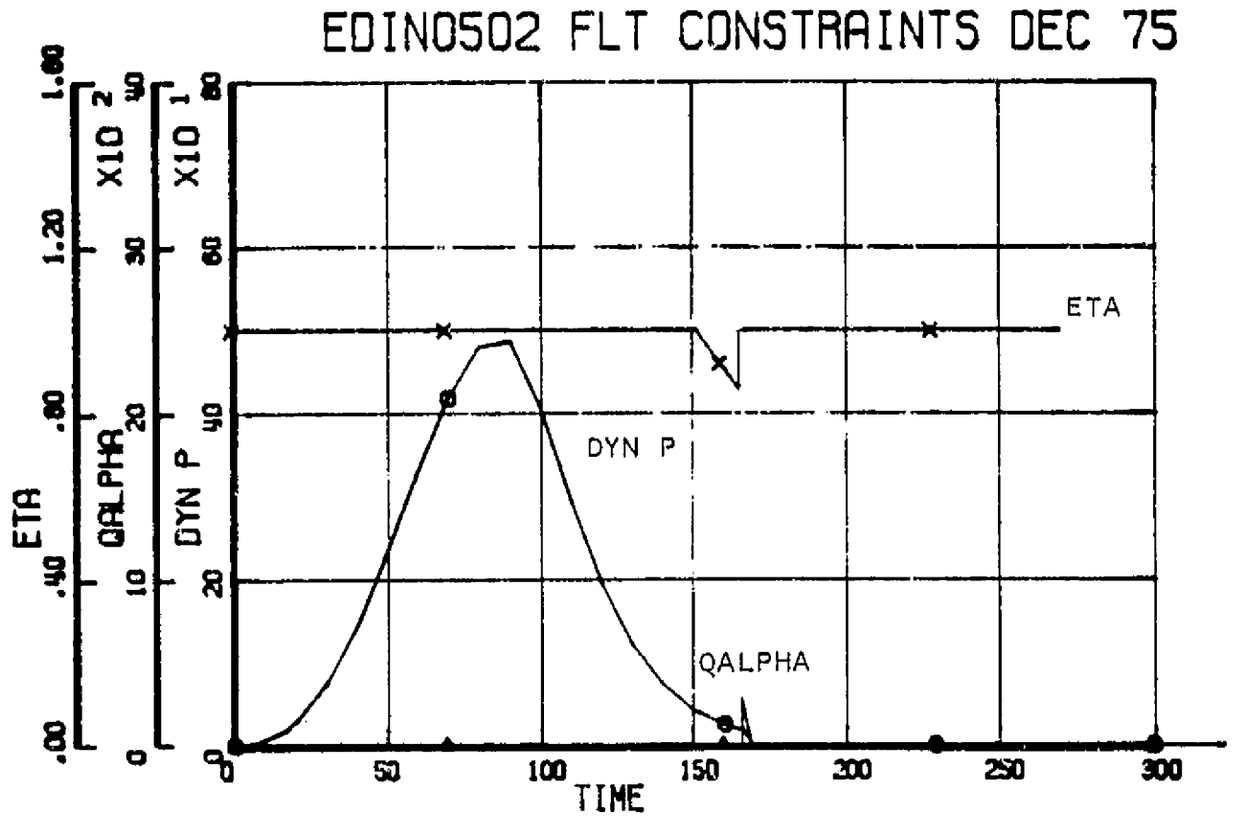
TIME
X10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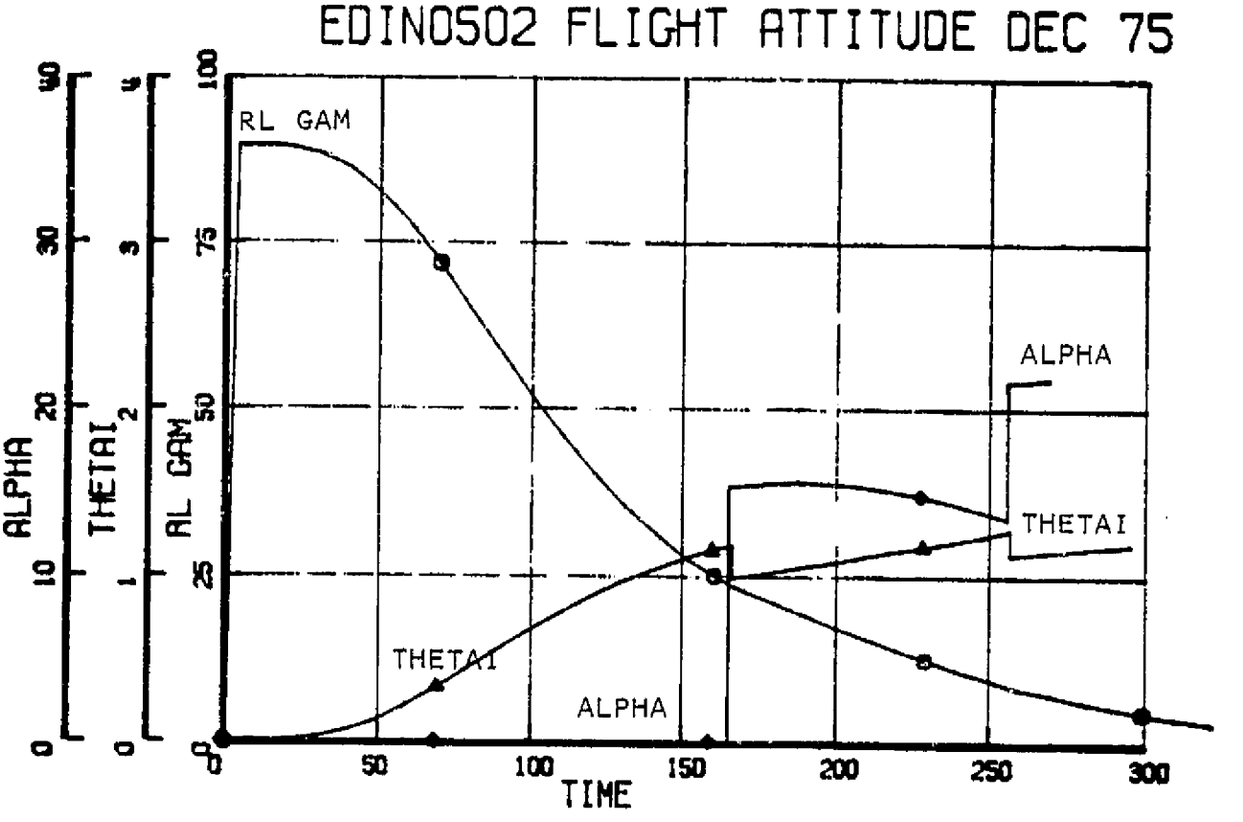
DYN P
QALPHA
TIME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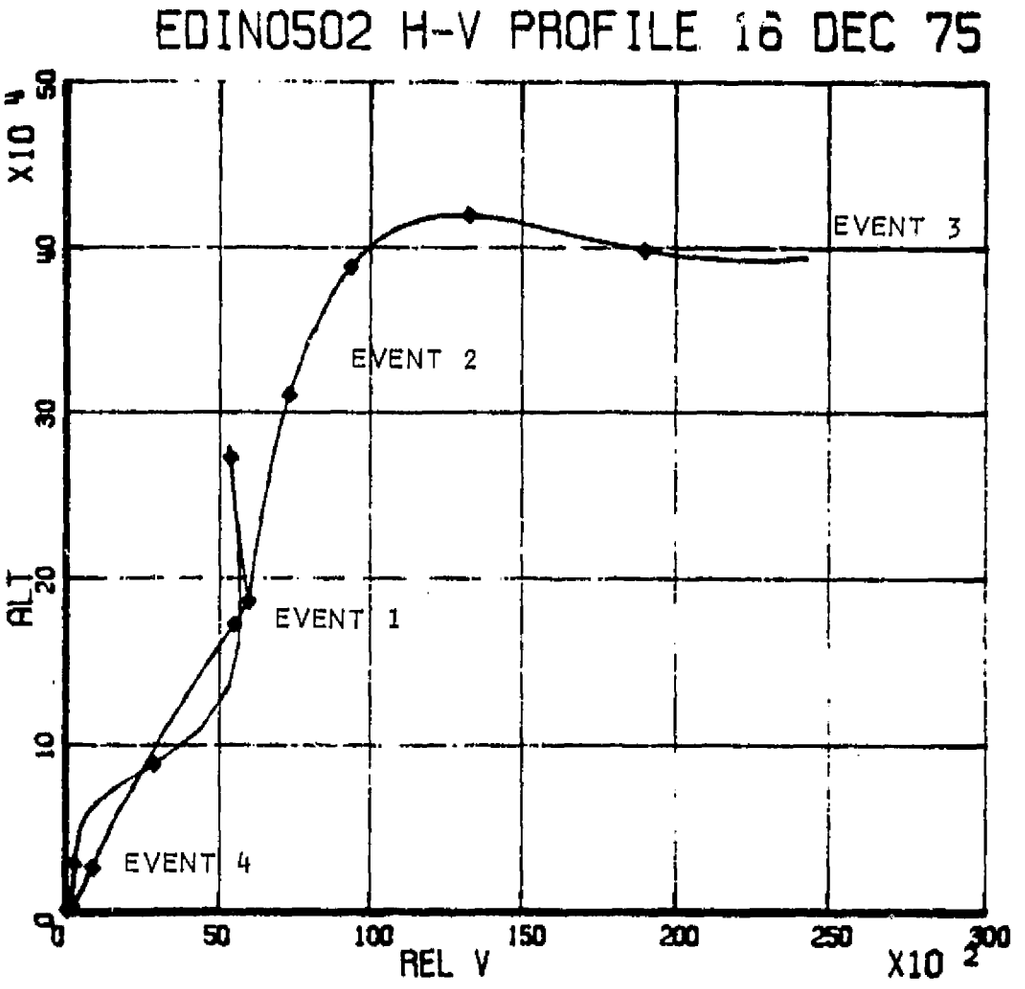
ALPHA
THETAI
RL GAM
RL GAM
ALPHA
THETAI
THETAI
ALPHA
TIME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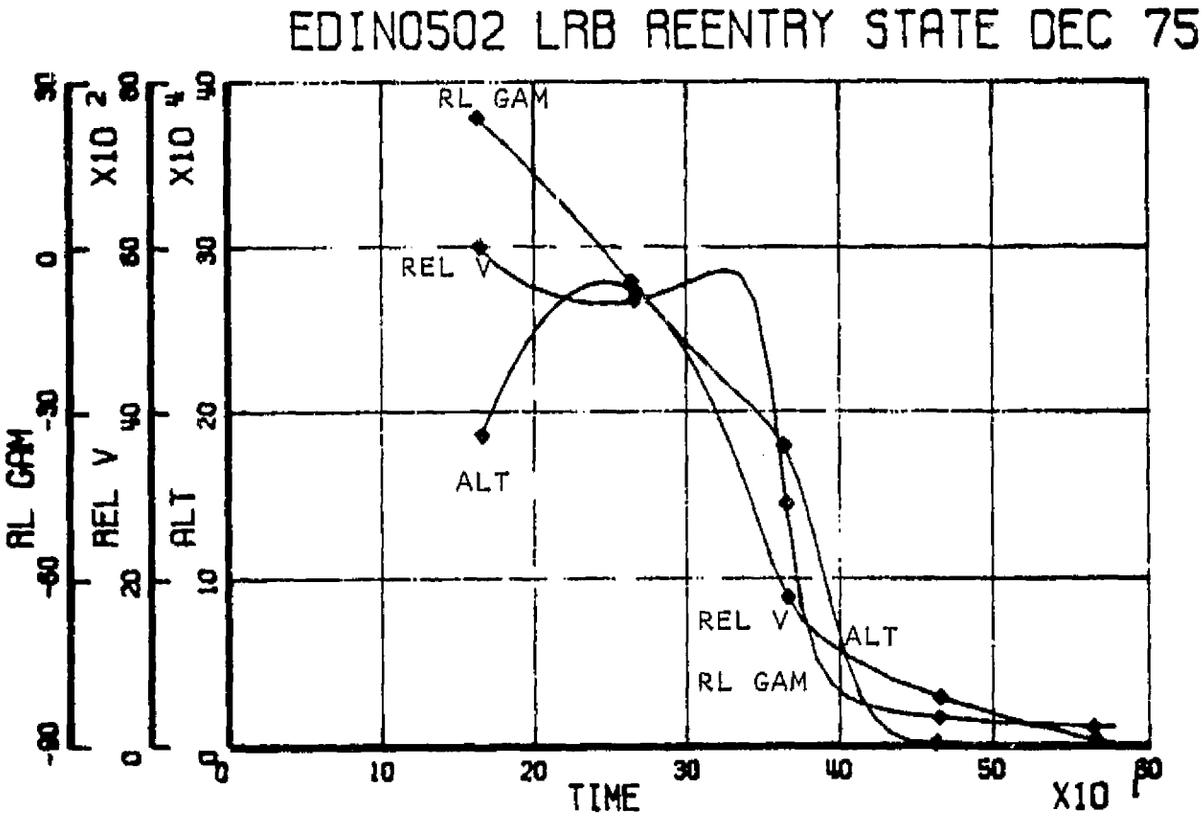
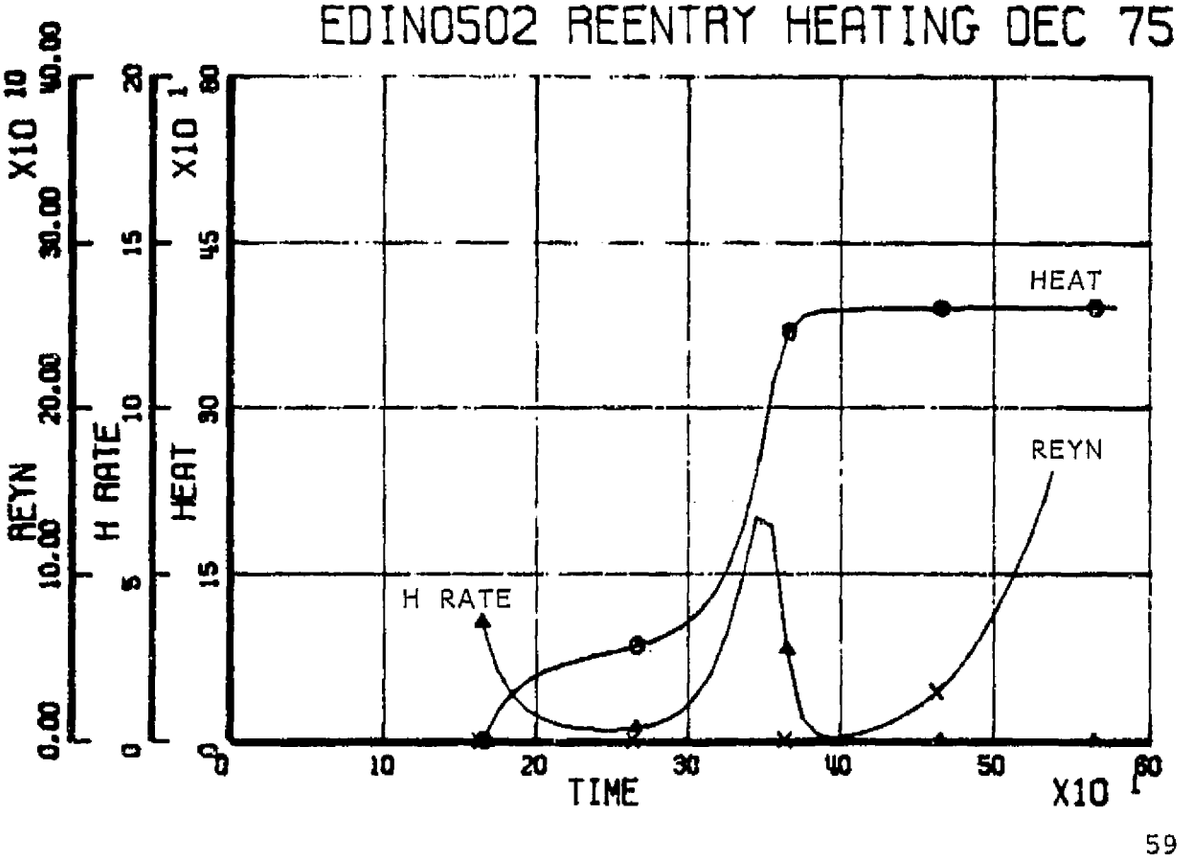
X10 4
ALT
0
10
20
30
40
50
EVENT 1
EVENT 2
EVENT 3
EVENT 4
0
50
100
150
200
250
300
REL V
X10 2


EDIN0502 LRB REENTRY STATE DEC 75
RL GAM
REL V
ALT
REL V
ALT
RL GAM
RL GAM
REL V
ALT
TIME
X10


EDIN0502 REENTRY HEATING DEC 75
HEAT
REYN
H RATE
H RATE
HEAT
REYN
TIME
X10

SIGMA CORPORATION

EDIN0503 DESIGN

SIMULATION RESULTS

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FORECASTER: EDIN DESIGN CENTER                          DATE: 10 OCT 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC          TIME: 19:07
STUDY NO: EDIN0503
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CONCEPT: A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 6.00 HIGH PRESSURE ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR REPLACEMENT OF THE SOLID ROCKET BOOSTERS.

MISSION: MAXIMUM PAYLOAD
DUE EAST LAUNCH FROM ETR
A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL MILE REFERENCE ORBIT.
A 100 FPS RCS TRANSLATION DELTA VEL.

TRAJECTORY: DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH PROFILE AND INITIAL TILT RATE.
- MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS/AOA
- END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO

ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY HIGH PRESSURE ENGINE THROTTLING AND/OR SSME THROTTLING.
- MAX DYNAMIC PRESSURE = 650.0 PSF
- MAX ACCELERATION = 3.0 G

PROPULSION: LRB: 6.00 HIGH PRESSURE ENGINES RATED AS FOLLOWS:
- THRUST(SL) = 800000.00 LBS
- THRUST(VAC) = 856800.00 LBS
- THROTTLE = 1.00 TO .500
- ISP(SL) = 327.60 SEC.
- ISP(VAC) = 350.80 SEC.
- FLOWRATE = 2442.2 LB/SEC
- EXIT AREA = 31.730 SQ FT
- MIX RATIO = 2.90:1

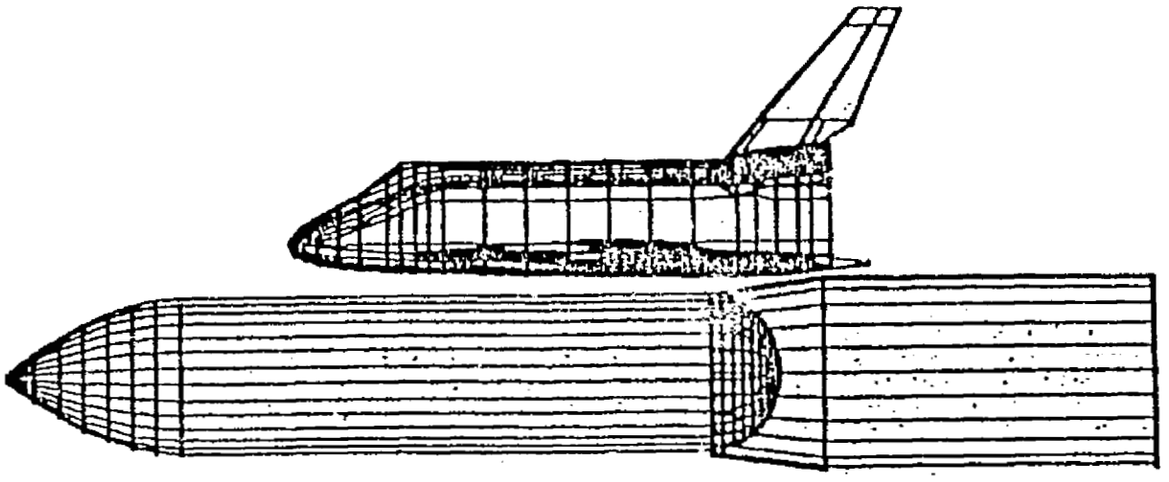
ORBITER: THREE SSME ENGINES RATED AS FOLLOWS:
- THRUST(SL) = 375000.00 LBS
- THRUST(VAC) = 470000.00 LBS
- THROTTLE = 1.09 TO .500
- ISP(SL) = 363.20 SEC
- ISP(VAC) = 455.20 SEC
- FLOWRATE = 1032.5 LB/SEC
- EXIT AREA = 44.896 SQ FT
- MIX RATIO = 6.00:1

AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
- REF AREA = 2557.0 SQ FT

STRUCTURE: ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND INCREASED UP PAYLOADS.

MASS PROPERTIES: MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC ASSUMPTIONS.
- LRB: WERS BASED ON SATURN TECHNOLOGY.
- ET: FIXED MASS FRACTION DISTRIBUTED IN ACCORDANCE WITH SHUTTLE ET WEIGHT STATEMENT.
- ORBITER: FEB 1975 SHUTTLE WITH MODS FOR INCREASED UP PAYLOAD.

EDIN0503 DESIGN SIMULATION RESULTS



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                      WEIGHTS SUMMARY REPORT
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.
GLOW                                                    4697514.81
.
ET LIFT-OFF WEIGHT                                      1805487.20
.
   ET INERT WEIGHT                        98039.26
   ET PROPELLANT                        1707528.81
.
LRB LIFT-OFF WEIGHT                                     2568623.78
.
   LRB INERT WEIGHT                      234013.29
   LRB PROPELLANT                       2334610.50
.
ORBITER LIFT-OFF WEIGHT                                  323404.00
.
   ORBITER INERT WEIGHT                  187254.00
   PAYLOAD                               136122.01
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ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2862.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	19874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	28054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2929.	
ELECTRICAL CONVERSION	6960.	
HYDRAULIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 100K PAYLD	390.	
ORBITER EMPTY WEIGHT		151715.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1840.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16149.	
ORBITER INERT WEIGHT		187254.
PAYLOAD		136150.
ORBITER PRELAUNCH WEIGHT		323404.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		16260.
BHD	79.	
FWD FRAME	51.	
FWD OGIVE	1342.	
AFT OGIVE	4511.	
XT 745 FRAME	313.	
BARREL	2917.	
INTERTANK FRAME	1064.	
AFT DOME	3469.	
SLOSH BAFFLES	2514.	
INTERTANK		12708.
MACHINED BARREL PNLS	5088.	
SK/STGR BARREL PNLS	5500.	
STABILIZING FRAMES(4)	1505.	
SRB THRST XT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	68.	
BARREL PNLS SPLICES (8)	113.	
FRAME STABLIZERS	244.	
ET ASSY FASTENERS	191.	

LH2 TANK		99688.
FWD DOME	1902.	
FT 1129.9 FRAME	1877.	
BARREL NO.4	6525.	
FT 1377 FRAME	655.	
BARREL NO.3	6559.	
FT 1624 FRAME	655.	
BARREL NO.2	6563.	
FT 1871 FRAME	8056.	
BARREL NO.1	6942.	
FT 2058 FRAME	3929.	
AFT DOME	2225.	
THERMAL PROTECTION		7729.
LOX TANK	1657.	
INTERTANK	1720.	
LH2 TANK	4037.	
PROP (MECH+ELEC)	314.	
PROPULSION AND MECHANICAL SYSTEMS		4504.
LOX FEED SYS	1926.	
LOX ANTIGEYER SYS	181.	
LOX VENT SYS	101.	
LOX PRESS. SYS	219.	
LH2 FEED SYS	551.	
LH2 RECIR. SYS	36.	
LH2 VENT SYS	153.	
LH2 PRESS. SYS	168.	
HELIUM INJ. SYS	85.	
INTERTANK PURGE SYS	95.	
HAZARD GAS DETECTION SYS	10.	
FAIRINGS AND CONDUIT	407.	
LINE SUPTS. AND ATTACHS.	637.	
ELECTRICAL SYSTEM		278.
ET WIRING ASSY	188.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	17.	
CABLING ATTACHS.+SENSOR SUPTS.	73.	
ORB/SRB ATTACHMENTS		5358.
ORBITER SUPPORTS	3677.	
UMBILICAL BEAM	754.	
ORB/ET ATTACH FTGS	280.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	647.	
MANUFACTURING VARIATION WT.		506.
EMPTY WEIGHT		87230.
UNUSABLE FLUIDS		1486.
LH2 IN TANK	273.	
LH2 IN LINE	56.	
LOX IN LINE	157.	
PRE-PRESS.+INFLIGHT GASES		4405.
GH2	1145.	
GOX	3223.	
HELIUM	37.	
SEPARATION HARDWARE		-6.
SRB SUPPORTS	0.	
ORB FITTINGS	6.	
FLT PERF RES		5912.
ET INERT WT		98039.
MAIN PROPELLANTS		1707448.
LOX	1463527.	
LH2	243921.	
ET LIFT-OFF WEIGHT		1805487.
MASS FRACTION		.9490

LIQUID ROCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		93058.
INTEGRAL LOX TANK	20679.	
INTEGRAL FUEL TANK	14022.	
INTERSTAGE	8583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	33615.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		2189.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1248.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		799.
ELECTRICAL SYSTEM	684.	
CONTROL SYSTEM	115.	
INSTRUMENTATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		68963.
ENGINES (DRY)	38100.	
ACCESSORIES	416.	
GIMBAL SYSTEM	5283.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	8389.	
OXIDIZER SYSTEM	12419.	
SEPARATION AND RECOVERY SYSTEM		16665.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	5724.	
FLOATATION SYSTEM	104.	
RECOVERY AIDS	102.	
FITTINGS AND SUPPORTS	197.	
RETRO SYS (100 F/S DEL V)	3174.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		190111.
CONTINGENCY		0.
EMPTY WEIGHT		190111.
PROPELLANT RESIDUALS		39767.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	3871.	
TRAPPED FUEL TANK GASES	3440.	
FROST TRAPPED	434.	
TRAPPED FUEL	10064.	
TRAPPED LOX	18073.	
IN-FLIGHT LOSSES		4135.
FUEL LOSSES	1619.	
LOX LOSSES	2229.	
MAIN PROPELLANTS		2334611.
FUEL	595137.	
LOX	1739474.	
BLOW		2568624.
MASS FRACTION (BASED ON INERT WT)		.9089

ORBITER WT	323404.0
ET WEIGHT	1805487.2
LRB STAGE WT	2568623.8
GLOW	4697514.9
EFFECTIVE STG 1 LAMBDA	.92712
EFFECTIVE STG 2 LAMBDA	.92652

```
CONVERGENCE DATA:
      GLOW                                    4697515.
         THROW WEIGHT                                    421415.
         PAYLOAD                                         136122.
      TOTAL VIDEAL                             30170.5
         STAGE 1 VIDEAL                                  10779.6
         STAGE 2 VIDEAL                                  19390.9
      TOTAL PROPELLANT                        4042086.
         LRB PROPELLANT                                 2334558.
         ET PROPELLANT                                  1707529.

STAGE 1 SIZING DATA
      AVERAGE SP. IMP.                          352.91
      LIFT-OFF T/W                               1.277
      MAXIMUM Q                                  541.6
      TIME AT MAX Q                               80.0
      STG 1 MAX LF                                3.00
      TIME AT MAX LF                             159.0
      EFF WDOT/LRB                             14460.1
      EFF WDOT/EVENT 1                         17836.4

STAGING CONDITIONS:
      WEIGHT                                  1817865.
      REL VELOCITY (FPS)                        6368.4
      REL F.P. ANGLE (DEG)                       24.97
      ALTITUDE (FT)                            203542.
      TIME (SEC)                                161.45
      ATT AFTER STG (DEG)                         1.11
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MISSION SUMMARY: OCTOBER 10, 1975
.
   PARAMETER            EVENT 1   EVENT 2   EVENT 3   EVENT 4
-------------------------------------------------------------
TIME (SEC)                161.4     233.2     531.1     598.0
ALTITUDE (K FT)           203.5     348.6     394.4         0
REL VELOCITY (100 FPS)     63.7      81.4     243.0     201.3
REL GAMMA (DEG)            25.0      8.27      .588     -89.8
WEIGHT (K LBS)           4697.5    1583.9    1341.4     234.0
WEIGHT DROP (K LBS)       234.0         0         0         0
THROW WEIGHT (K LBS)     1583.9    1341.4    421.42         0
CUM VIDEAL (100 FPS)      107.8     132.1     301.7         0
DOWNRANGE (NMI)            44.4     135.2     922.7     280.3
.
.
EVENT 1   BECO/SEPARATION              EVENT 3  MECO/INJECTION
EVENT 2   RTLS/ABA CONSTRAINT          EVENT 4  LRB TOUCHDOWN
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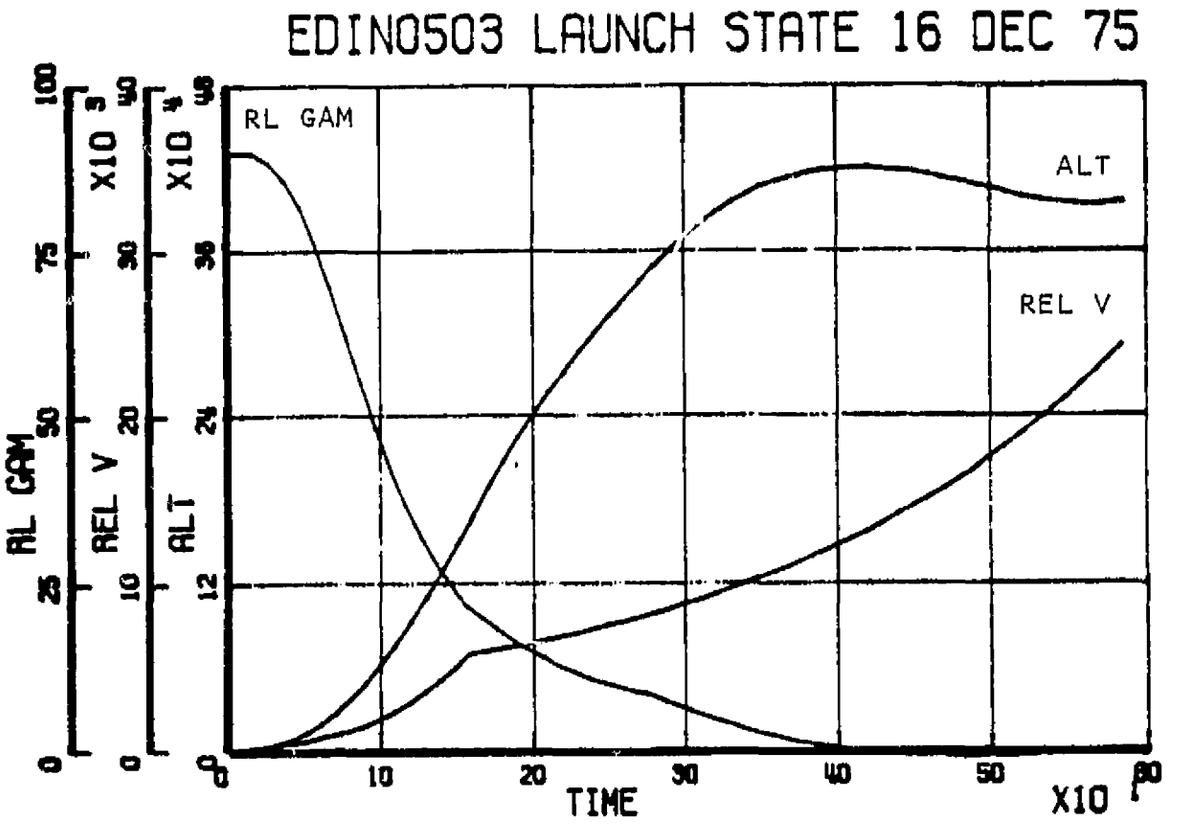
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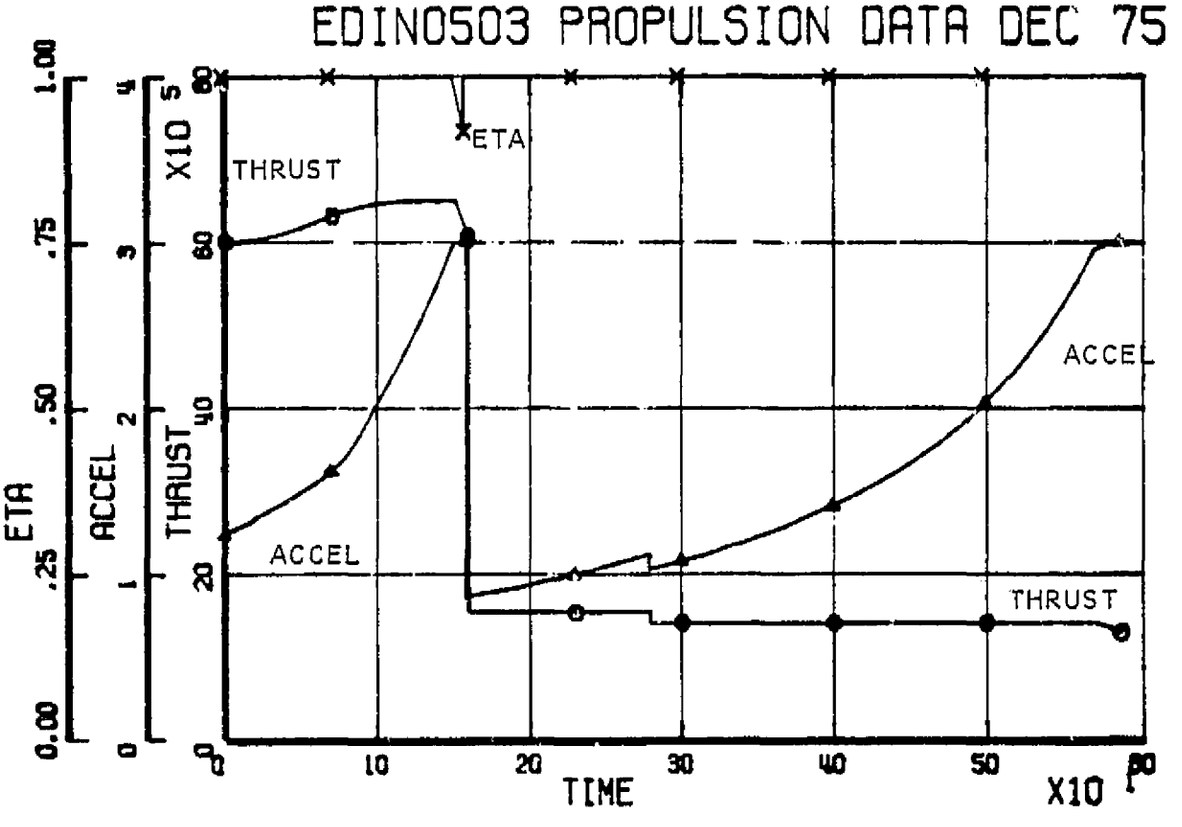
RL GAM
ALT
REL V
RL GAM
REL V
ALT
X10 3
X10 4
TIME
X10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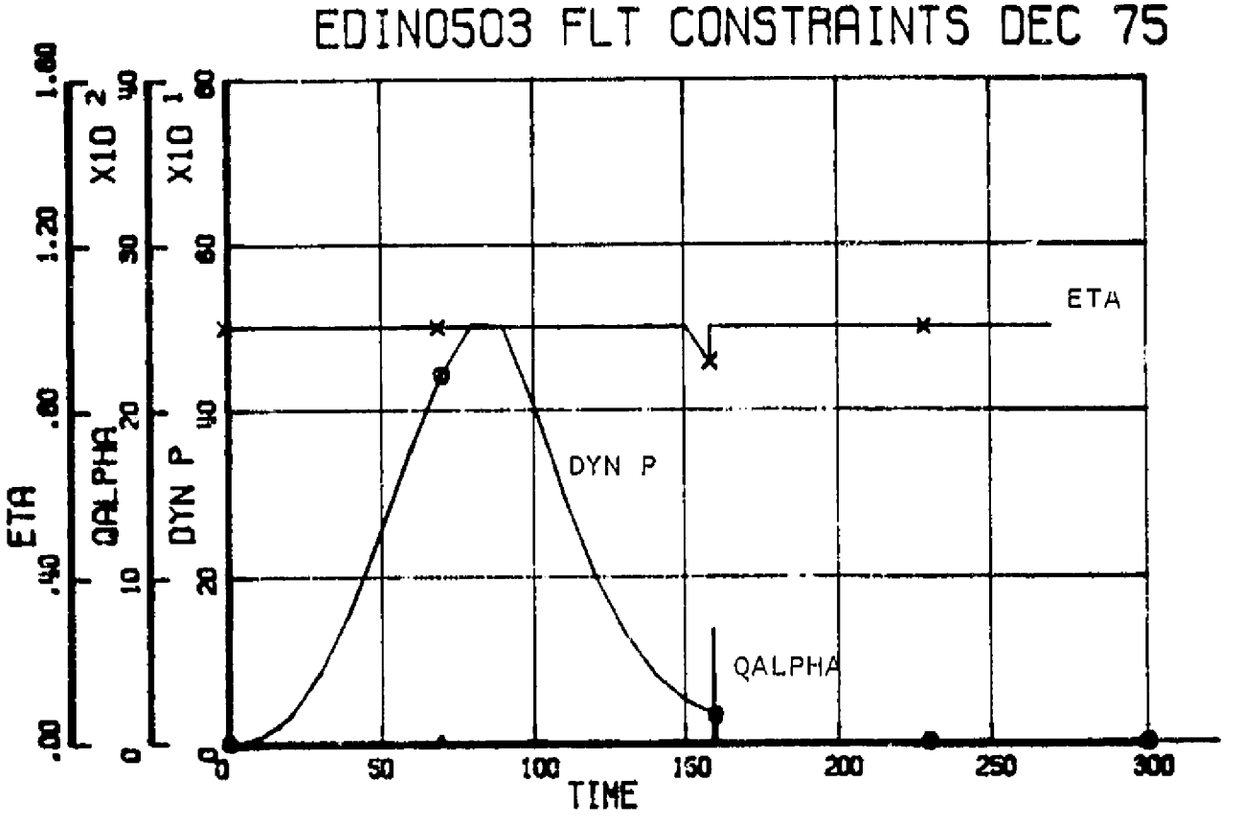
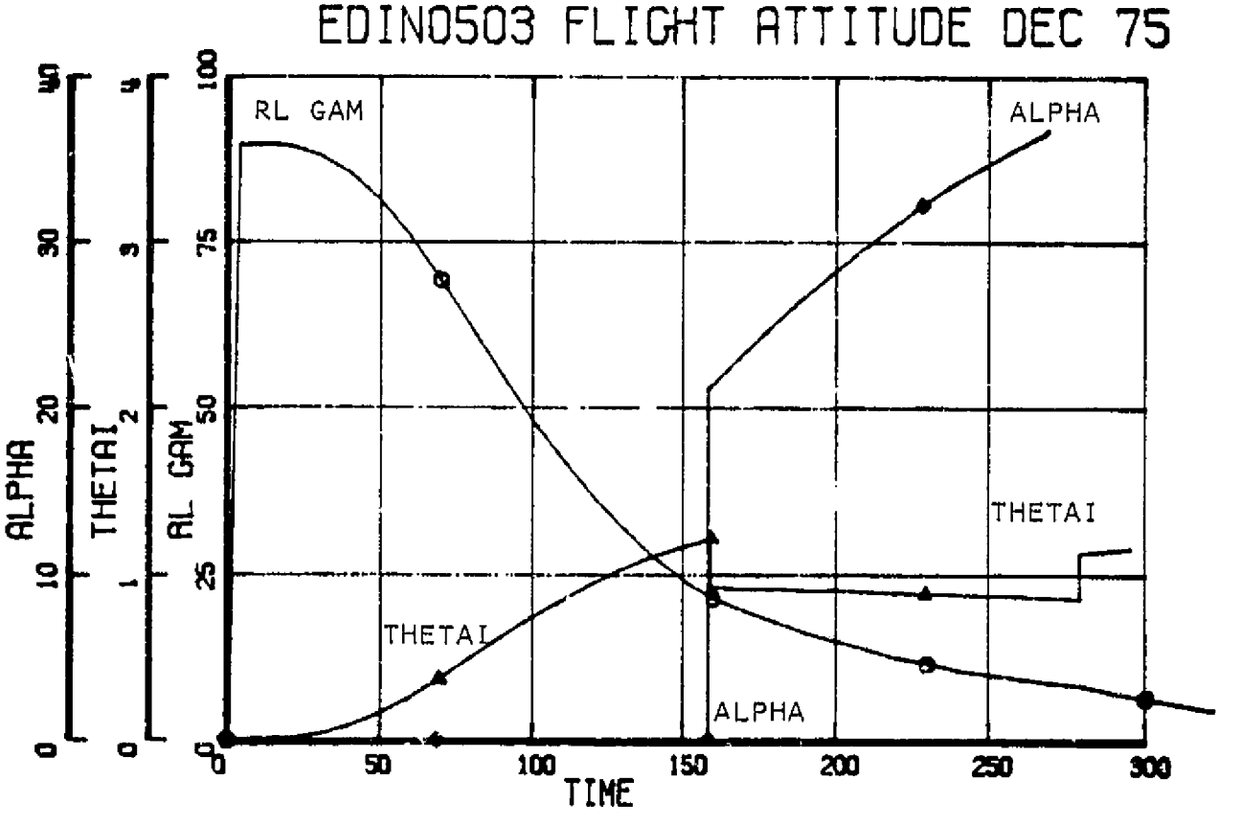
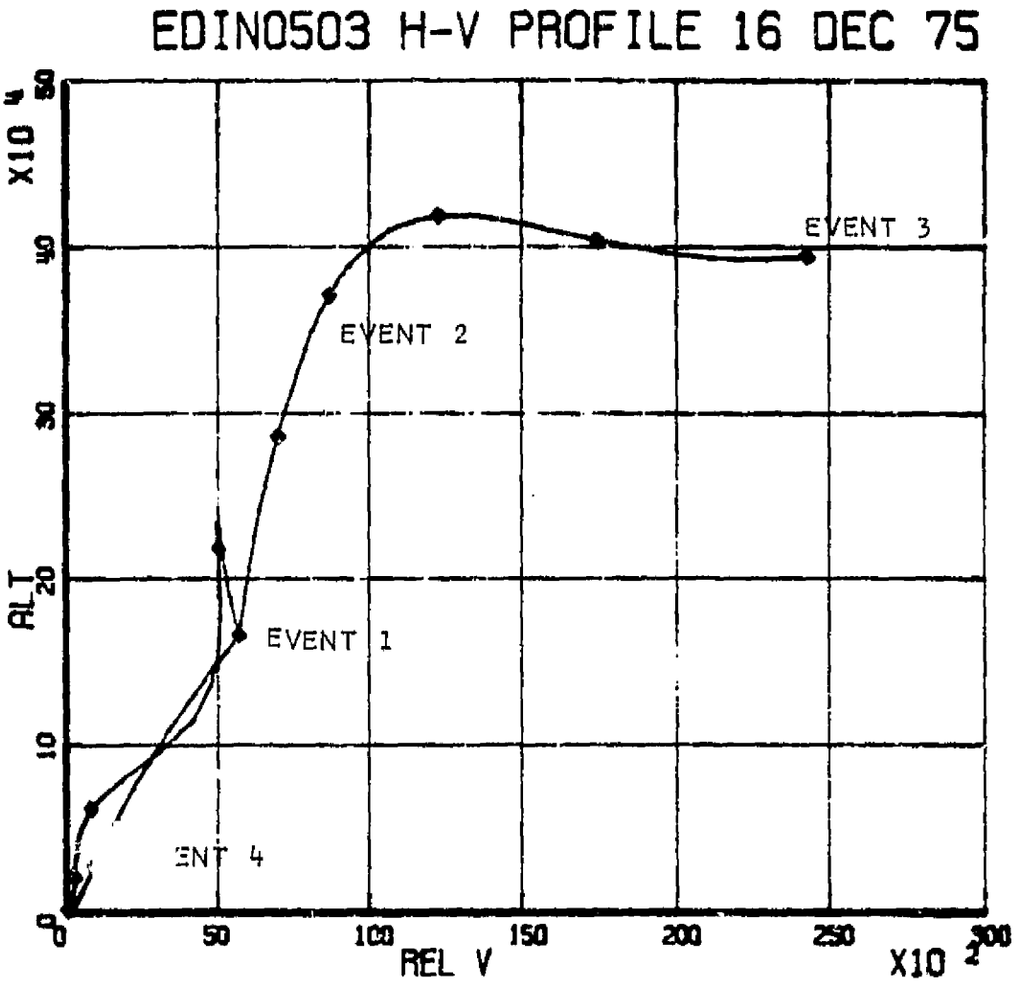
ETA
THRUST
ACCEL
ETA
ACCEL
THRUST
X10 5
TIME
X10


EDIN0503 FLT CONSTRAINTS DEC 75
ETA
QALPHA X10 2
DYN P X10 1
ETA
DYN P
QALPHA
TIME


EDIN0503 FLIGHT ATTITUDE DEC 75
ALPHA
THETAI
RL GAM
RL GAM
ALPHA
THETAI
THETAI
ALPHA
TIME


EDIN0503 H-V PROFILE 16 DEC 75
X10 4
ALT
0
10
20
30
40
50
EVENT 3
EVENT 2
EVENT 1
ENT 4
0
50
100
150
200
250
300
REL V
X10 2

SIGMA CORPORATION

EDIN0504 DESIGN

SIMULATION RESULTS

FORECASTER: EDIN DESIGN CENTER DATE: 19 NOV 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC TIME: 08:11
STUDY NO: EDIN0504

CONCEPT: A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 5.09 HIGH PRESSURE ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR REPLACEMENT OF THE SOLID ROCKET BOOSTERS.

MISSION: 140000.0 LB PAYLOAD
DUE EAST LAUNCH FROM ETR
A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL MILE REFERENCE ORBIT.
A 100 FPS RCS TRANSLATION DELTA VEL.

TRAJECTORY: DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH PROFILE AND INITIAL TILT RATE.
MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS/ROA
END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO
ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY HIGH PRESSURE ENGINE THROTTLING AND/OR SSME THROTTLING.
MAX DYNAMIC PRESSURE = 650.0 PSF
MAX ACCELERATION = 3.0 G

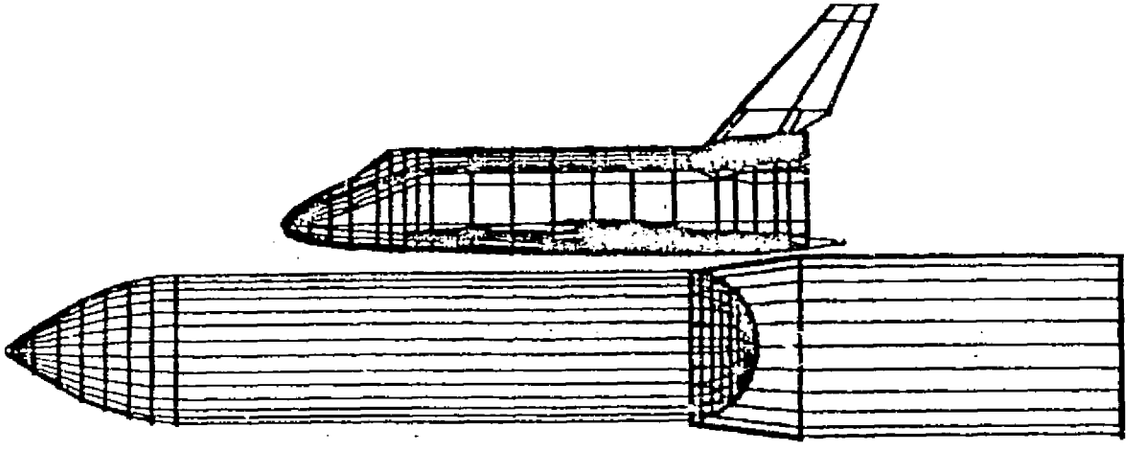
PROPULSION: LRB: 5.09 HIGH PRESSURE ENGINES RATED AS FOLLOWS:
THRUST(SL) = 800000.00 LBS
THRUST(VAC) = 856800.00 LBS
THROTTLE = 1.00 TO .500
ISP(SL) = 327.60 SEC.
ISP(VAC) = 350.80 SEC.
FLOWRATE = 2442.2 LB/SEC
EXIT AREA = 32.000 SQ FT
MIX RATIO = 2.90:1
ORBITER: THREE SSME ENGINES RATED AS FOLLOWS:
THRUST(SL) = 375000.00 LBS
THRUST(VAC) = 470000.00 LBS
THROTTLE = 1.09 TO .500
ISP(SL) = 363.20 SEC
ISP(VAC) = 455.20 SEC
FLOWRATE = 1032.5 LB/SEC
EXIT AREA = 44.896 SQ FT
MIX RATIO = 6.00:1

AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
REF AREA = 2557.0 SQ FT

STRUCTURE: ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND INCREASED UP PAYLOADS.

MASS PROPERTIES: MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC ASSUMPTIONS.
LRB: WERS BASED ON SATURN TECHNOLOGY.
ET: FIXED MASS FRACTION DISTRIBUTED IN ACCORDANCE WITH SHUTTLE ET WEIGHT STATEMENT.
ORBITER: FEB 1975 SHUTTLE WITH MODS FOR INCREASED UP PAYLOAD.

EDIN0504 DESIGN SIMULATION RESULTS



WEIGHTS SUMMARY REPORT

GLOW		4261415.81
ET LIFT-OFF WEIGHT		1878989.12
ET INERT WEIGHT	102458.0	
ET PROPELLANT	1776561.56	
LRB LIFT-OFF WEIGHT		2055172.86
LRB INERT WEIGHT	200441.21	
LRB PROPELLANT	1854731.67	
ORBITER LIFT-OFF WEIGHT		327254.00
ORBITER INERT WEIGHT	187254.00	
PAYLOAD	140000.00	

ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2862.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	19874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	28054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2929.	
ELECTRICAL CONVERSION	6960.	
HYDRAULIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 100K PAYLD	390.	
ORBITER EMPTY WEIGHT		151715.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1840.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16149.	
ORBITER INERT WEIGHT		187254.
PAYLOAD		140000.
ORBITER PRELAUNCH WEIGHT		327254.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		16917.
BHD	82.	
FWD FRAME	53.	
FWD OGIVE	1396.	
AFT OGIVE	4694.	
WT 745 FRAME	326.	
BARREL	3035.	
INTERTANK FRAME	1107.	
AFT DOME	3609.	
SLOSH BAFFLES	2615.	
INTERTANK		13222.
MACHINED BARREL PNLS	5294.	
SK/STGR BARREL PNLS	5722.	
STABILIZING FRAMES(4)	1566.	
SRB THRST WT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	71.	
BARREL PNLS SPLICES (8)	117.	
FRAME STABLIZERS	254.	
ET ASSY FASTENERS	198.	

LH2 TANK		41502.
FWD DOME	1979.	
XT 1129.9 FRAME	1953.	
BARREL NO.4	6789.	
XT 1377 FRAME	681.	
BARREL NO.3	6885.	
XT 1624 FRAME	681.	
BARREL NO.2	6829.	
XT 1871 FRAME	2139.	
BARREL NO.1	7223.	
XT 2058 FRAME	4088.	
AFT DOME	2315.	
THERMAL PROTECTION		8042.
LOX TANK	1724.	
INTERTANK	1790.	
LH2 TANK	4200.	
PROP (MECH+ELEC)	327.	
PROPULSION AND MECHANICAL SYSTEMS		4686.
LOX FEED SYS	2004.	
LOX ANTIGEYER SYS	188.	
LOX VENT SYS	106.	
LOX PRESS. SYS	228.	
LH2 FEED SYS	573.	
LH2 RECIR. SYS	37.	
LH2 VENT SYS	160.	
LH2 PRESS. SYS	169.	
HELIUM INJ. SYS	26.	
INTERTANK PURGE SYS	99.	
HAZARD GAS DETECTION SYS	10.	
FAIRINGS AND CONDUIT	424.	
LINE SUPTS. AND ATTACHS.	663.	
ELECTRICAL SYSTEM		290.
ET WIRING ASSY	196.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	18.	
CABLING ATTACHS.+SENSOR SUPTS.	76.	
ORB/SRB ATTACHMENTS		5574.
ORBITER SUPPORTS	3826.	
UMBILICAL BEAM	784.	
ORB/ET ATTACH FTGS	291.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	673.	
MANUFACTURING VARIATION WT.		527.
EMPTY WEIGHT		90759.
UNUSABLE FLUIDS		506.
LH2 IN TANK	285.	
LH2 IN LINE	58.	
LOX IN LINE	163.	
PRE-PRESS.+INFLIGHT GASES		4583.
GH2	1191.	
GOX	3353.	
HELIUM	39.	
SEPARATION HARDWARE		6.
SRB SUPPORTS	0.	
ORB FITTINGS	6.	
FLT PERF RES		6603.
ET INERT WT		102458.
MAIN PROPELLANTS		1776531.
LOX	1522741.	
LH2	253790.	
ET LIFT-OFF WEIGHT		1878989.
MASS FRACTION		.9490

LIQUID ROCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		83633.
INTEGRAL LOX TANK	16395.	
INTEGRAL FUEL TANK	8715.	
INTERSTAGE	8583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	33780.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		1998.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1058.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		677.
ELECTRICAL SYSTEM	580.	
CONTROL SYSTEM	97.	
INSTRUMENTATION SYSTEM		1520.
INSTRUME.ITATION	1520.	
PROPULSION		58188.
ENGINES (DRY)	32305.	
ACCESSORIES	706.	
GIMBAL SYSTEM	8959.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	4822.	
OXIDIZER SYSTEM	7040.	
SEPARATION AND RECOVERY SYSTEM		14755.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	4549.	
FLOTATION SYSTEM	82.	
RECOVERY AIDS	81.	
FITTINGS AND SUPPORTS	157.	
RETRO SYS (100 F/S DEL V)	2522.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		167688.
CONTINGENCY		0.
EMPTY WEIGHT		167688.
PROPELLANT RESIDUALS		29693.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	3069.	
TRAPPED FUEL TANK GASES	2138.	
FROST TRAPPED	315.	
TRAPPED FUEL	8042.	
TRAPPED LOX	14329.	
IN-FLIGHT LOSSES		3060.
FUEL LOSSES	1293.	
LOX LOSSES	1767.	
MAIN PROPELLANTS		1854732.
FUEL	475572.	
LOX	1379159.	
BLOW		2055173.
MASS FRACTION (BASED ON INERT WT)		.9025

ORBITER WT	327254.0
ET WEIGHT	1878989.1
LRB STAGE WT	2055172.9
GLOW	4261415.9
EFFECTIVE STG 1 LAMBDA	.92183
EFFECTIVE STG 2 LAMBDA	.92522

```
CONVERGENCE DATA:
      SLOW                                          4261416.
         DROP WEIGHT                                              102453.
         PAYLOAD                                                  140200.
      TOTAL VIDEAL                                   30610.7
         STAGE 1 VIDEAL                                           10115.3
         STAGE 2 VIDEAL                                           20114.4
      TOTAL PROPELLANT                              3431065.
         LPB PROPELLANT                                         1654583.
         ET PROPELLANT                                          1776563.

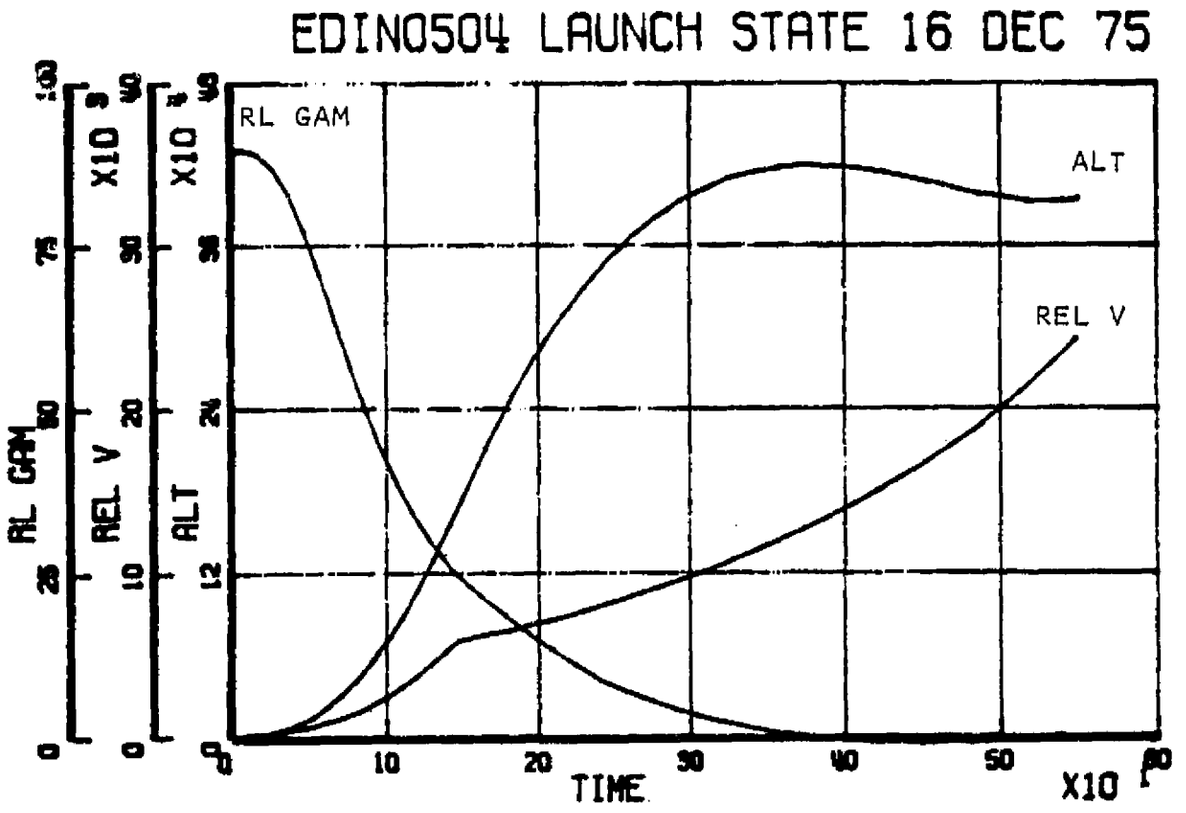
STAGE 1 SIZING DATA
      AVERAGE SP. IMP.                                 [illegible]
      LIFT-OFF T/W                                     [illegible]
      MAXIMUM Q                                        [illegible]
      TIME AT MAX Q                                      30.0
      STG 1 MAX LF                                       3.00
      TIME AT MAX LF                                   [illegible]
      EFF WDOT LPB                                   18304.4
      EFF WDOT EVENT 1                               19680.7

STAGING CONDITIONS:
      WEIGHT                                        1838021.
      REL VELOCITY (FPS)                              5920.9
      REL F.P. ANGLE (DEG)                              24.46
      ALTITUDE (FT)                                 172565.
      TIME (SEC)                                      150.78
      ATT AFTER STG (DEG)                               .39
```


MISSION SUMMARY: NOVEMBER 19, 1975

PARAMETER	EVENT 1	EVENT 2	EVENT 3	EVENT 4
TIME (SEC)	130.7	246.9	551.9	580.6
ALTITUDE (K FT)	172.5	348.6	394.2	0
REL VELOCITY (100 FPS)	59.2	81.4	843.0	1.86
REL GAMMA (DEG)	24.7	8.87	.588	-89.8
WEIGHT (K LBS)	4261.4	1697.6	1373.0	200.4
WEIGHT DROP (K LBS)	200.4	0	102.5	0
THROW WEIGHT (K LBS)	1697.6	1173.0	127.45	0
CUM VIDEAL (100 FPS)	101.2	132.2	303.3	0
DOWNRANGE (NMI)	38.38	156.0	960.3	223.4

EVENT 1 BECO/SEPARATION EVENT 3 MECO/INJECTION
EVENT 2 RTLS/ABA CONSTRAINT EVENT 4 LPB TOUCHDOWN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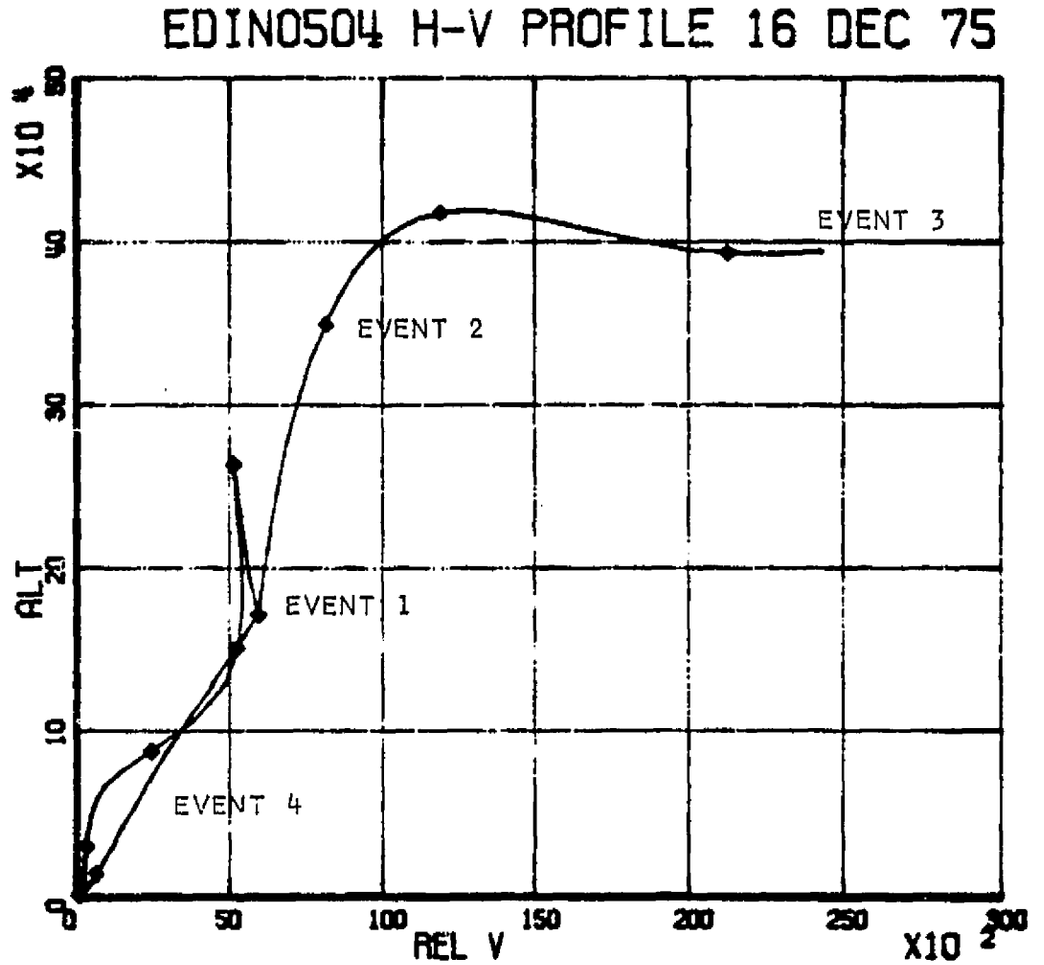
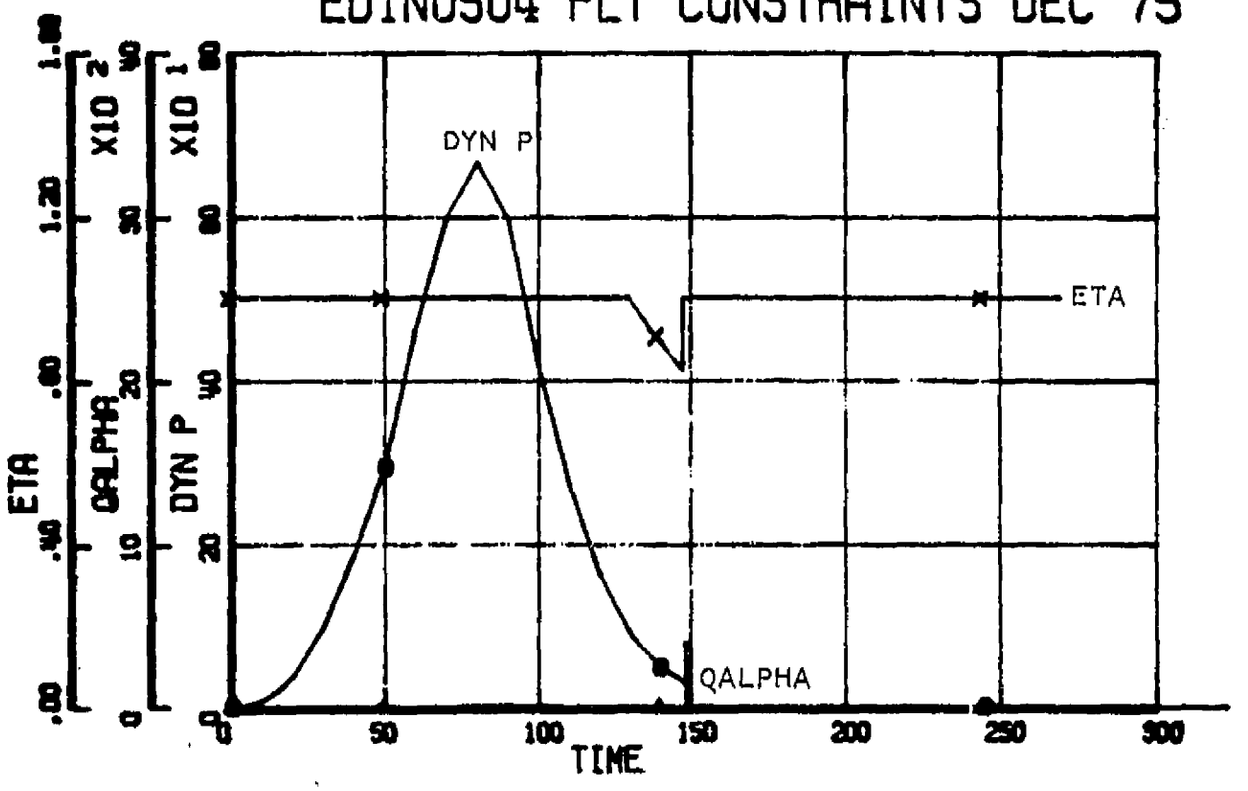
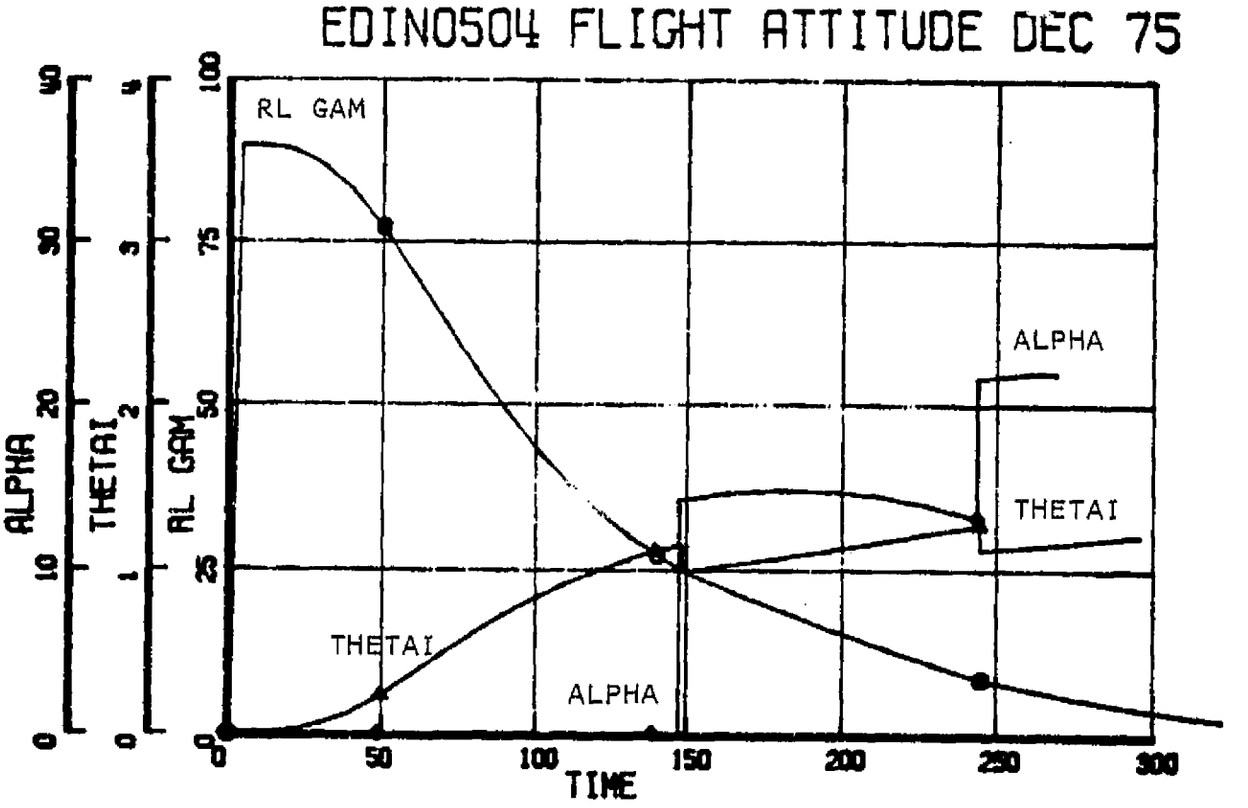
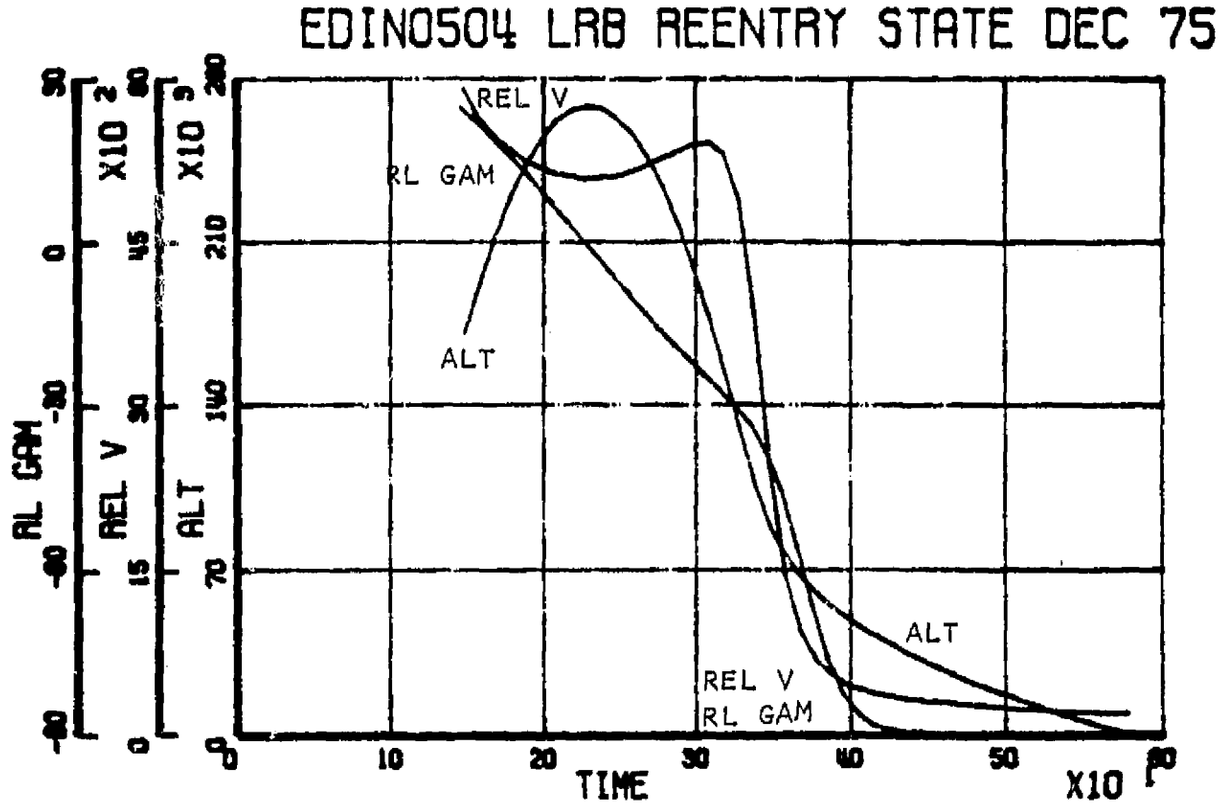
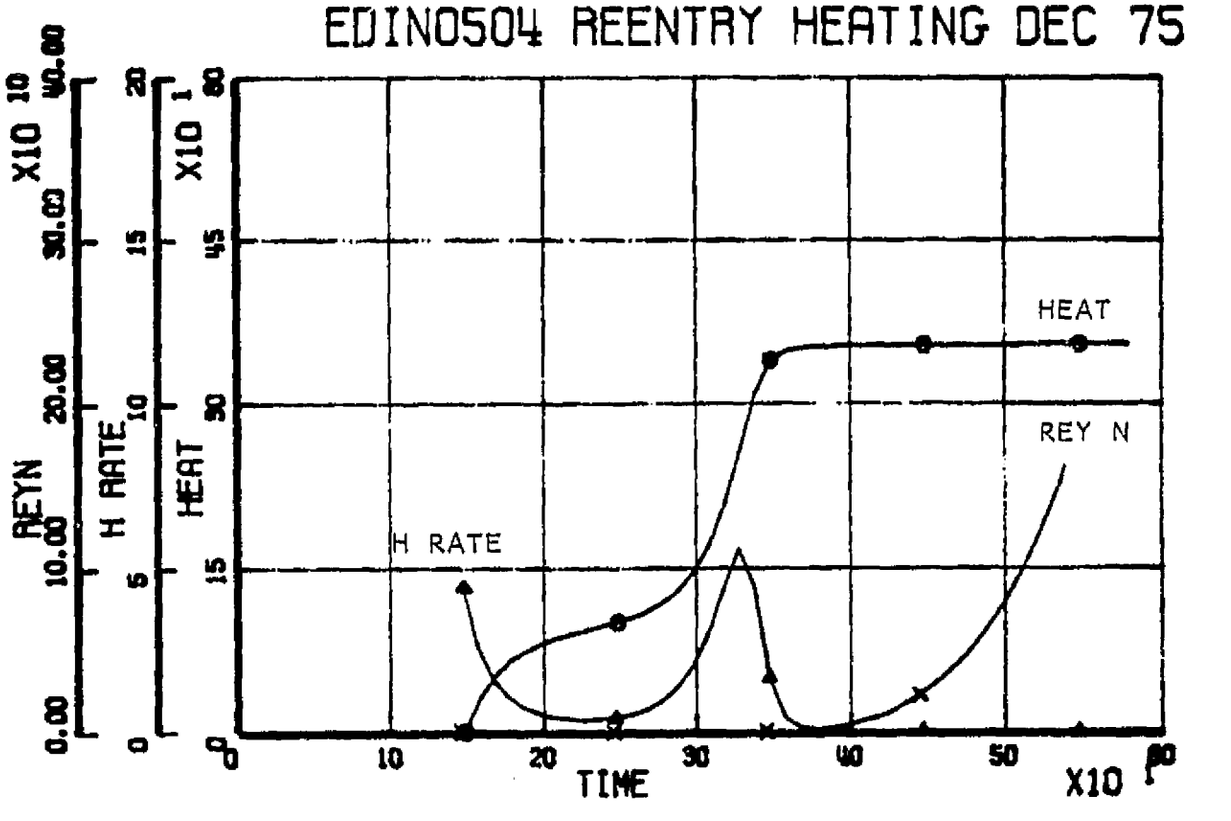
RL GAM
ALT
REL V
RL GAM
X10 ft
REL V
ALT
TIME
X10 sec


EDIN0504 H-V PROFILE 16 DEC 75
X10 ft
EVENT 3
EVENT 2
EVENT 1
EVENT 4
ALT
REL V
X10 ft/sec


EDIN0504 FLT CONSTRAINTS DEC 75
ETA
QALPHA
X10 2
DYN P
X10 1
DYN P
ETA
QALPHA
TIME


EDIN0504 FLIGHT ATTITUDE DEC 75
ALPHA
THETAI
RL GAM
RL GAM
ALPHA
THETAI
THETAI
ALPHA
TIME


EDIN0504 LRB REENTRY STATE DEC 75
REL V
RL GAM
ALT
ALT
REL V
RL GAM
RL GAM
REL V
ALT
X10 2
X10 3
TIME
X10


EDIN0504 REENTRY HEATING DEC 75
HEAT
REY N
H RATE
REYN
H RATE
HEAT
X10 10
X10 1
TIME
X10

EDIN0504A DESIGN

SIMULATION RESULTS

```
**********************************************************************
FORECASTER: EDIN DESIGN CENTER                          DATE: 4 DEC 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC          TIME: 12:45
STUDY NO: EDIN0504
**********************************************************************

.
CONCEPT:      A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 6.61 HIGH
              PRESSURE ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR
              REPLACEMENT OF THE SOLID ROCKET BOOSTERS.

.
MISSION:      150000.0 LB PAYLOAD
              DUE EAST LAUNCH FROM ETR
              A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL
              MILE REFERENCE ORBIT.
              A 100 FPS RCS TRANSLATION DELTA VEL.

.
TRAJECTORY:   DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH
              PROFILE AND INITIAL TILT RATE.
                 MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS-ROA
                 END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO
              ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY HIGH
              PRESSURE ENGINE THROTTLING AND/OR SIME THROTTLING.
                 MAX DYNAMIC PRESSURE = 650.0 PSF
                 MAX ACCELERATION     = 3.0 G

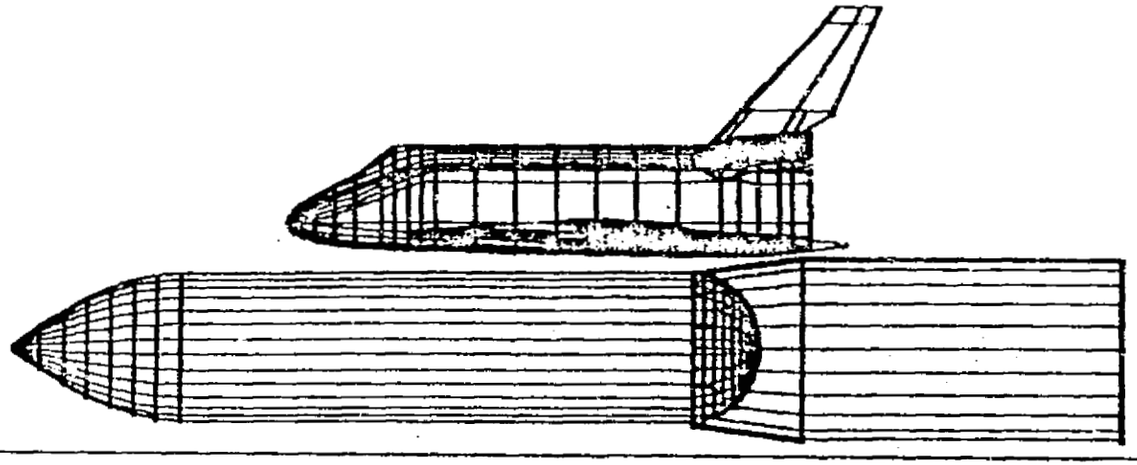
.
PROPULSION:   LRB: 6.61 HIGH PRESSURE ENGINES RATED AS FOLLOWS:
                 THRUST(SL)  = 800000.00 LBS
                 THRUST(VAC) = 986293.00  LBS
                 THROTTLE    = 1.00 TO .500
                 ISP(SL)     = 321.00 SEC.
                 ISP(VAC)    = 347.60 SEC.
                 FLOWRATE    = 2498.2 LB/SEC
                 EXIT AREA   = 32.000 SQ FT
                 MIX RATIO   = 2.50:1
              ORBITER: THREE SIME ENGINES RATED AS FOLLOWS:
                 THRUST(SL)  = 375000.00 LBS
                 THRUST(VAC) = 470000.00 LBS
                 THROTTLE    = 1.09 TO .500
                 ISP(SL)     = 363.20 SEC
                 ISP(VAC)    = 455.20 SEC
                 FLOWRATE    = 1032.5 LB/SEC
                 EXIT AREA   = 44.896 SQ FT
                 MIX RATIO   = 6.00:1

.
AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION
              WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS
              WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
                 REF AREA    = 2557.6 SQ FT

.
STRUCTURE:    ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS
              ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND
              INCREASED UP PAYLOADS.

.
MASS          MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC
PROPERTIES:   ASSUMPTIONS.
                 LRB: WERE BASED ON SATURN TECHNOLOGY.
                 ET: FIXED MASS FRACTION DISTRIBUTED IN
                     ACCORDANCE WITH SHUTTLE ET WEIGHT
                     STATEMENT.
                 ORBITER: FEB 1975 SHUTTLE WITH MODS FOR
                     INCREASED UP PAYLOAD.
```

EDIN0504A DESIGN SIMULATION RESULTS



WEIGHTS SUMMARY REPORT

GLOW		4804473.56
ET LIFT-OFF WEIGHT		1904993.38
ET INERT WEIGHT	103931.98	
ET PROPELLANT	1801061.42	
LRB LIFT-OFF WEIGHT		2561666.34
LRB INERT WEIGHT	228415.21	
LRB PROPELLANT	2333251.19	
ORBITER LIFT-OFF WEIGHT		337814.00
ORBITER INERT WEIGHT	187814.00	
PAYLOAD	150000.00	

ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2962.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	13874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	28054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2329.	
ELECTRICAL CONVERSION	6960.	
HYDRAULIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1387.	
WT PENALTY FOR 150K PAYLD	950.	
ORBITER EMPTY WEIGHT		152275.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1340.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16149.	
ORBITER INERT WEIGHT		187814.
PAYLOAD		150000.
ORBITER PRELAUNCH WEIGHT		337814.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		17151.
BHD	84.	
FWD FRAME	54.	
FWD OGIVE	1415.	
AFT OGIVE	4758.	
XT 745 FRAME	330.	
BARREL	3077.	
INTERTANK FRAME	1123.	
AFT DOME	3659.	
SLOSH BAFFLES	2651.	
INTERTANK		13404.
MACHINED BARREL PNLS	5367.	
SK/STGR BARREL PNLS	5801.	
STABILIZING FRAMES(4)	1587.	
SRB THRST XT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	78.	
BARREL PNLS SPLICES (8)	119.	
FRAME STABLIZERS	257.	
ET ASSY FASTENERS	201.	

LH2 TANK		42075.
FWD DOME	2006.	
XT 1129.3 FRAME	1960.	
BARREL NO.4	6882.	
XT 1377 FRAME	691.	
BARREL NO.3	6919.	
XT 1624 FRAME	691.	
BARREL NO.2	6923.	
XT 1871 FRAME	2168.	
BARREL NO.1	7322.	
XT 2058 FRAME	4145.	
AFT DOME	2347.	
THERMAL PROTECTION		8153.
LOX TANK	1748.	
INTERTANK	1815.	
LH2 TANK	4258.	
PROP (MECH+ELEC)	332.	
PROPULSION AND MECHANICAL SYSTEMS		4750.
LOX FEED SYS	2031.	
LOX ANTIGEYER SYS	191.	
LOX VENT SYS	107.	
LOX PRESS. SYS	231.	
LH2 FEED SYS	561.	
LH2 RECIR. SYS	38.	
LH2 VENT SYS	162.	
LH2 PRESS. SYS	171.	
HELIUM INJ. SYS	26.	
INTERTANK PURGE SYS	101.	
HAZARD GAS DETECTION SYS	10.	
FAIRINGS AND CONDUIT	429.	
LINE SUPTS. AND ATTACHS.	672.	
ELECTRICAL SYSTEM		294.
ET WIRING ASSY	198.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	18.	
CABLING ATTACHS.+SENSOR SUPTS.	77.	
ORB/SRB ATTACHMENTS		5651.
ORBITER SUPPORTS	3878.	
UMBILICAL BEAM	795.	
ORB/ET ATTACH FTGS	295.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	683.	
MANUFACTURING VARIATION WT.		534.
EMPTY WEIGHT		92012.
UNUSABLE FLUIDS		513.
LH2 IN TANK	298.	
LH2 IN LINE	59.	
LOX IN LINE	166.	
PRE-PRESS.+INFLIGHT GASES		4647.
GH2	1208.	
GOX	3400.	
HELIUM	39.	
SEPARATION HARDWARE		6.
SRB SUPPORTS	0.	
ORB FITTINGS	6.	
FLT PERF RES		6754.
ET INERT WT		103938.
MAIN PROPELLANTS		1801061.
LOX	1543767.	
LH2	257294.	
ET LIFT-OFF WEIGHT		1904993.
MASS FRACTION (BASED ON INERT WEIGHT		.94544

LIQUID POCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		93476.
INTEGRAL LOX TANK	19812.	
INTEGRAL FUEL TANK	12203.	
INTERSTAGE	8583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	36718.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		2136.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1195.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		766.
ELECTRICAL SYSTEM	655.	
CONTROL SYSTEM	110.	
INSTRUMENTATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		66517.
ENGINES (DRY)	41388.	
ACCESSORIES	306.	
GIMBAL SYSTEM	3884.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	6268.	
OXIDIZER SYSTEM	9715.	
SEPARATION AND RECOVERY SYSTEM		15644.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	5096.	
FLOTATION SYSTEM	92.	
RECOVERY AIDS	91.	
FITTINGS AND SUPPORTS	175.	
RETRO SYS (100 F/S DEL V)	2865.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		186975.
CONTINGENCY		0.
EMPTY WEIGHT		186975.
PROPELLANT RESIDUALS		37492.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	3709.	
TRAPPED FUEL TANK GASES	2994.	
FROST TRAPPED	401.	
TRAPPED FUEL	11273.	
TRAPPED LOX	17316.	
IN-FLIGHT LOSSES		3948.
FUEL LOSSES	1813.	
LOX LOSSES	2135.	
LRB INERT WT		229415.
MAIN PROPELLANTS		2333251.
FUEL	666643.	
LOX	1666608.	
BLOW		2561666.
MASS FRACTION (BASED ON INERT WT)		.91083

ORBITER WT	337814.0
ET WEIGHT	1904993.4
LRB WEIGHT	2561666.3
GLOW	4804473.7
STG 1 LAMBDA	.32500
STG 2 LAMBDA	.32686

```
CONVERGENCE DATA:
       GLOW                                    4804474.
       TARGET PAYLOAD                           150000.
          ACTUAL PAYLOAD                                    150224.
       TOTAL VIDEAL                             30065.0
          STAGE 1 VIDEAL                                      9637.1
          STAGE 2 VIDEAL                                     20427.9
       TOTAL PROPELLANT                        4134089.
          LRB PROPELLANT                                    2333217.
          ET PROPELLANT                                     1800871.
       STAGE JETTISON WEIGHTS
          STAGE 1 JETTISON WT                                228415.
          STAGE 2 JETTISON WT                                103938.

 STAGE 1 SIZING DATA
       AVERAGE SP. IMP.                          346.33
       LIFT-OFF T/W                               1.350
       MAXIMUM Q                                  649.5
       TIME AT MAX Q                               72.8
       STG 1 MAX LF                                3.00
       TIME AT MAX LF                             134.0
       EFF WDOT/LRB                             16274.6
       EFF WDOT/EVENT 1                         19650.8

 STAGING CONDITIONS:
       WEIGHT                                  1987214.
       REL VELOCITY (FPS)                         5948.6
       REL F.P. ANGLE (DEG)                        23.70
       ALTITUDE (FT)                            171048.
       TIME (SEC)                                 143.37
       ATT AFTER STG (DEG)                          .97
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**************************************************************************
.
MISSION I MMARY: DECEMBER 6, 1975
.
   PARAMETER            EVENT 1   EVENT 2   EVENT 3   EVENT 4
-------------------------------------------------------------
TIME (SEC)                143.4     244.1     559.7     552.5
ALTITUDE (K FT)           171.0     348.6     394.3         0
REL VELOCITY (100 FPS)     59.5      81.4     243.0     1.988
REL GAMMA (DEG)            23.7      8.28      .528     -89.8
WEIGHT (K LBS)           4804.5    1758.8    1418.6     228.4
WEIGHT DROP (K LBS)       2?F.4         0     103.9         0
THROW WEIGHT (K LBS)     175?.8    1418.6    338.04         0
CUM VIDEAL (100 FPS)      98.37     129.8     300.7         0
DOWNRANGE (NMI)            39.1     163.3     993.0     223.0
.
.
EVENT 1    BECO/SEPARATION              EVENT 3  MECO/INJECTION
EVENT 2    RTLS/AOA CONSTRAINT          EVENT 4  LRB TOUCHDOWN
.
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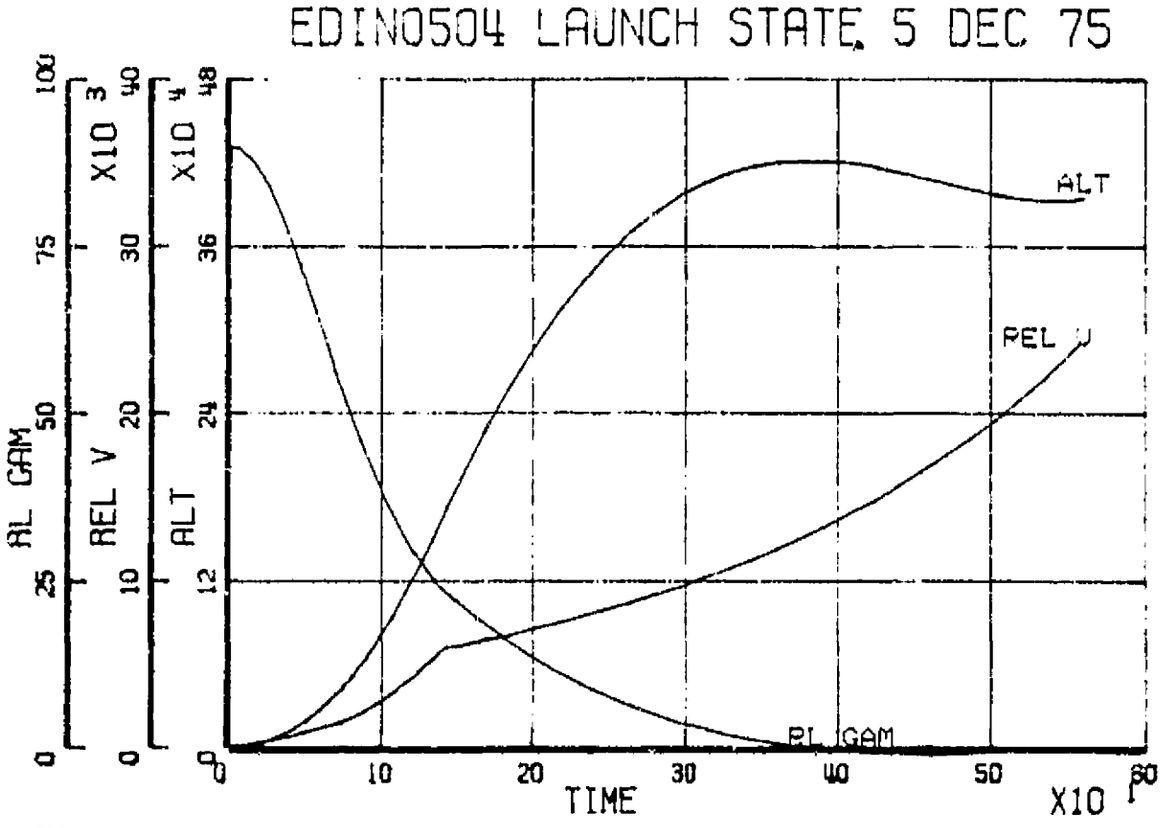
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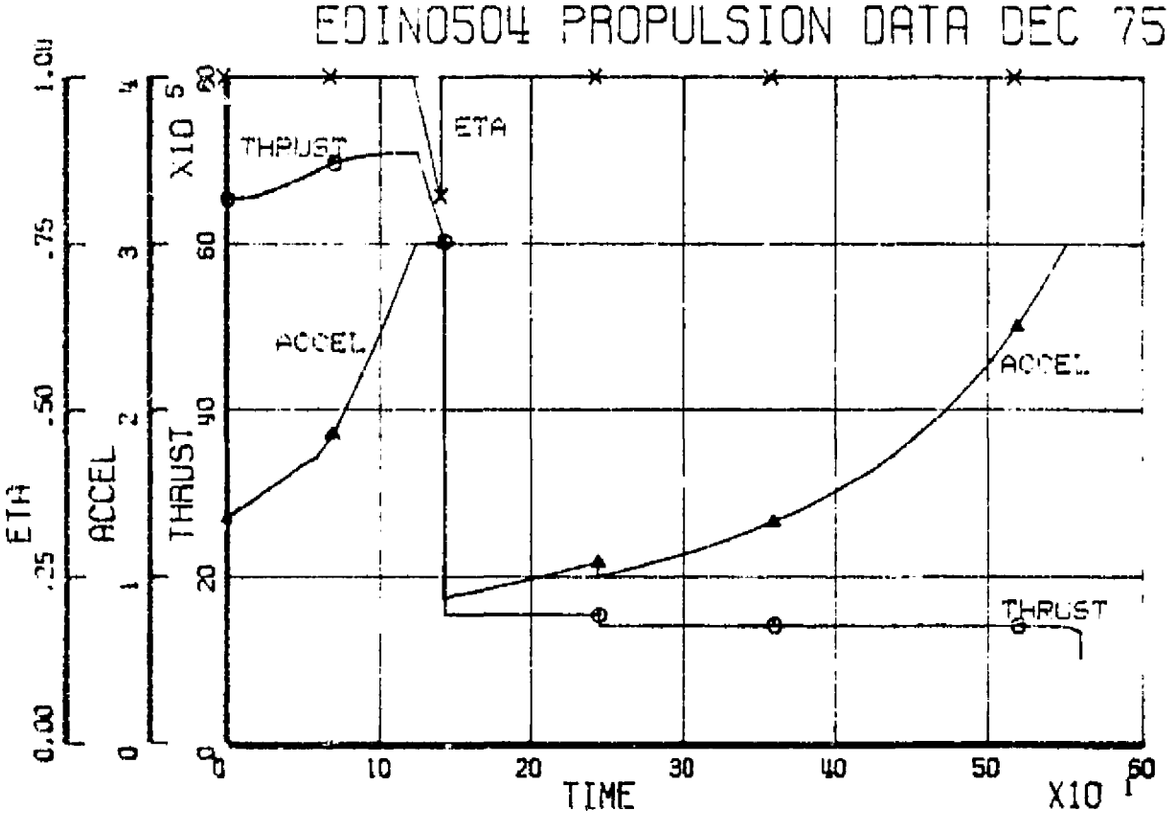
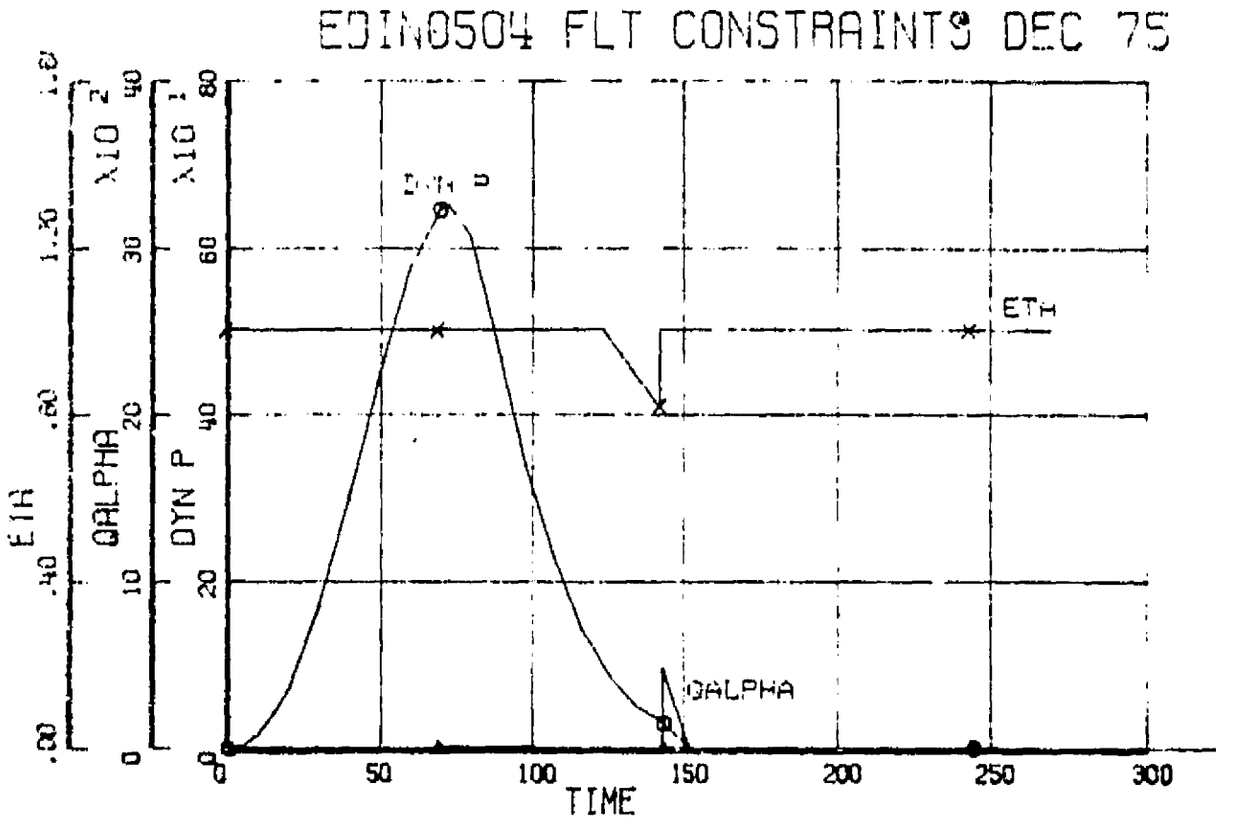
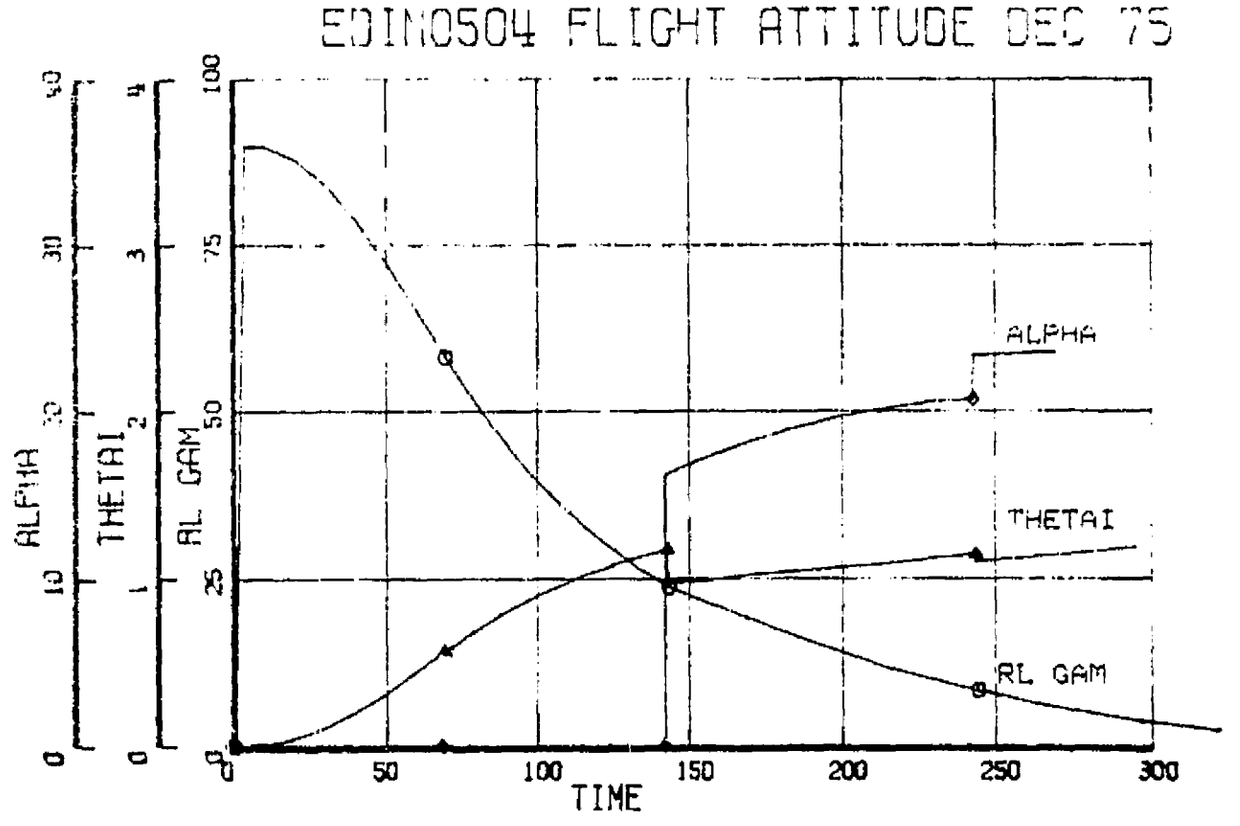
RL GAM
REL V
X10 3
ALT
X10 4
ALT
REL V
RL GAM
TIME
X10


EDIN0504 PROPULSION DATA DEC 75
ETA
ACCEL
X10 5
THRUST
THRUST
ETA
ACCEL
ACCEL
THRUST
TIME
X10


EDIN0504 FLT CONSTRAINTS DEC 75
ETH
QALPHA
DYN P
TIME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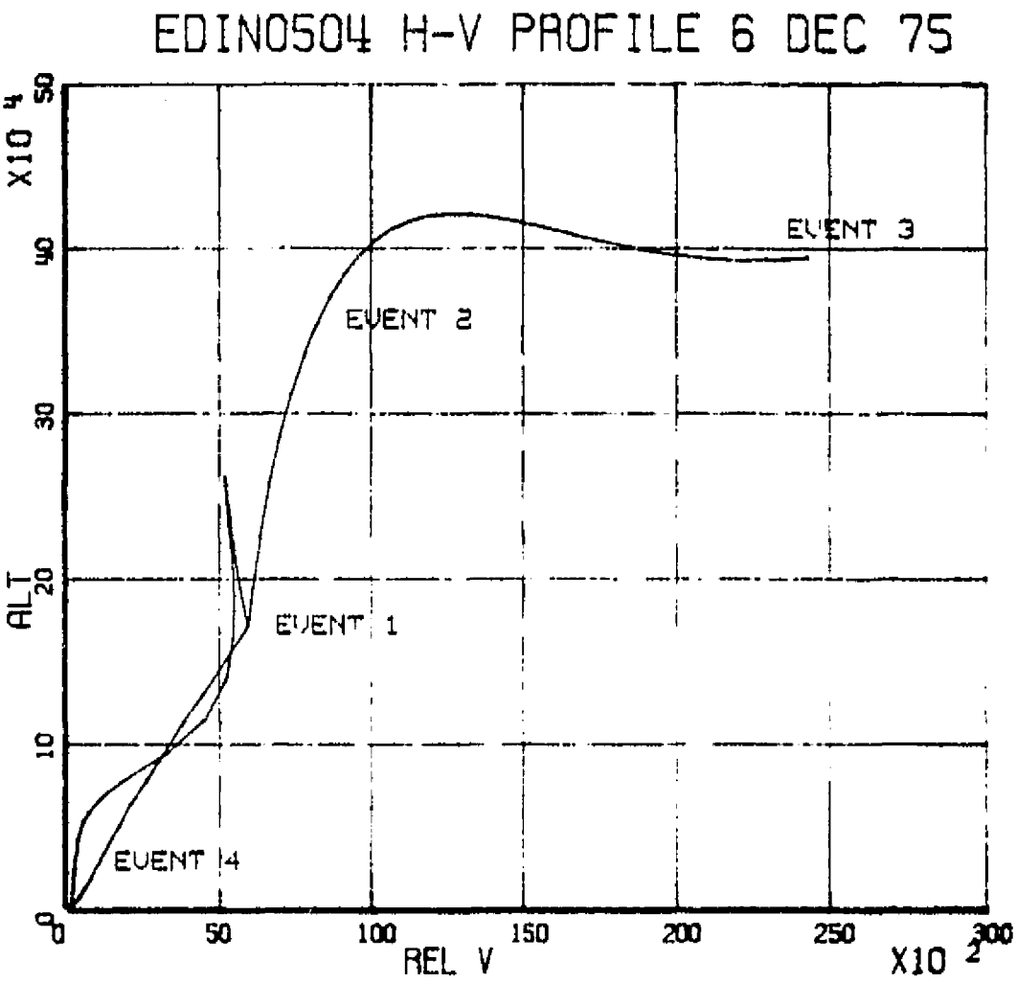
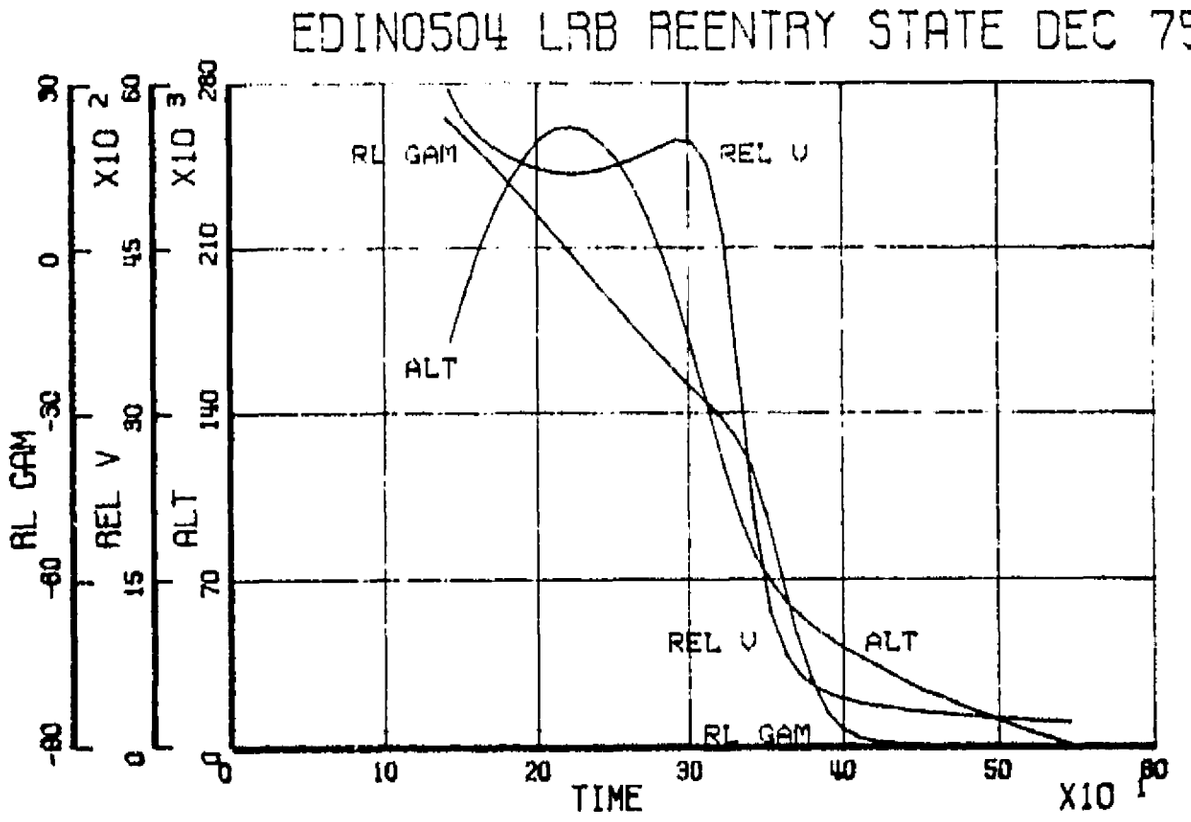
ALPHA
THETAI
RL GAM
TIME


EDINO504 H-V PROFILE 6 DEC 75
ALT
X10 4
0
10
20
30
40
50
0
50
100
150
200
250
300
REL V
X10 2
EVENT 1
EVENT 2
EVENT 3
EVENT 4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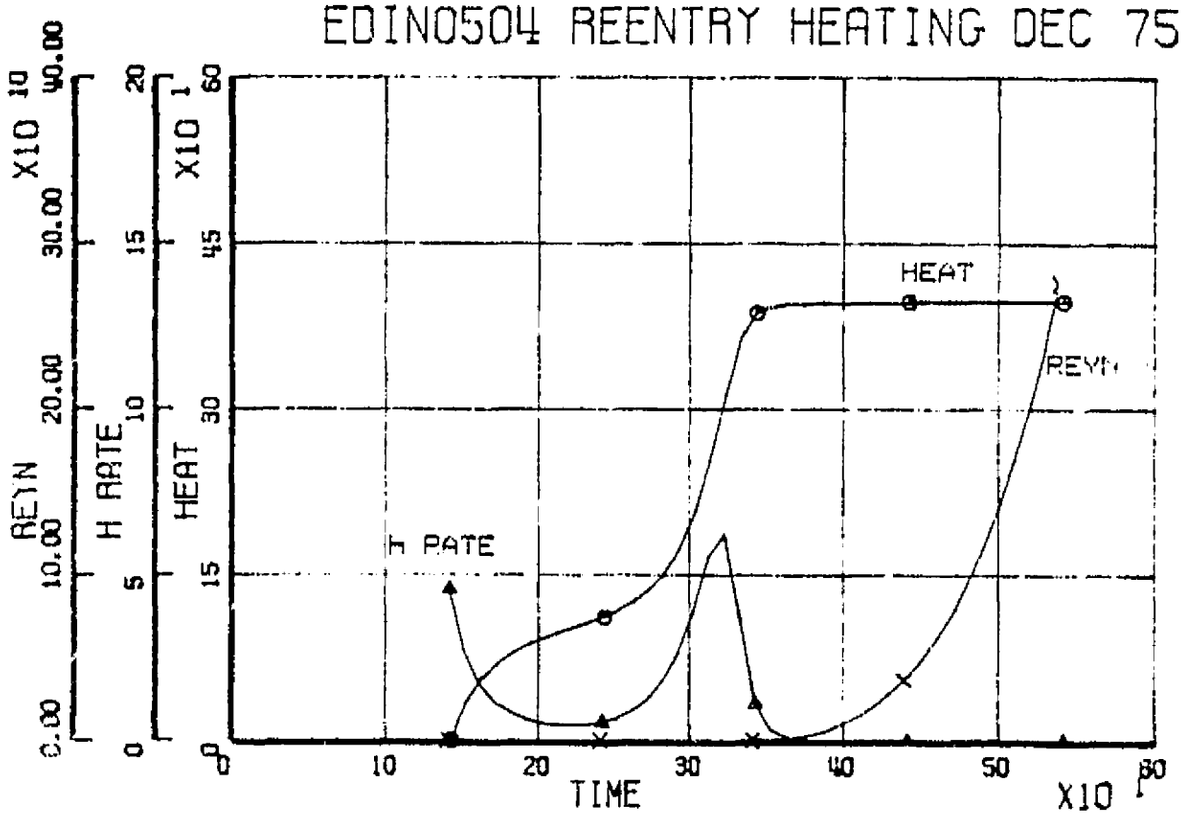
RL GAM
REL V
ALT
REL V
ALT
RL GAM
TIME
X10 1
X10 2
X10 3

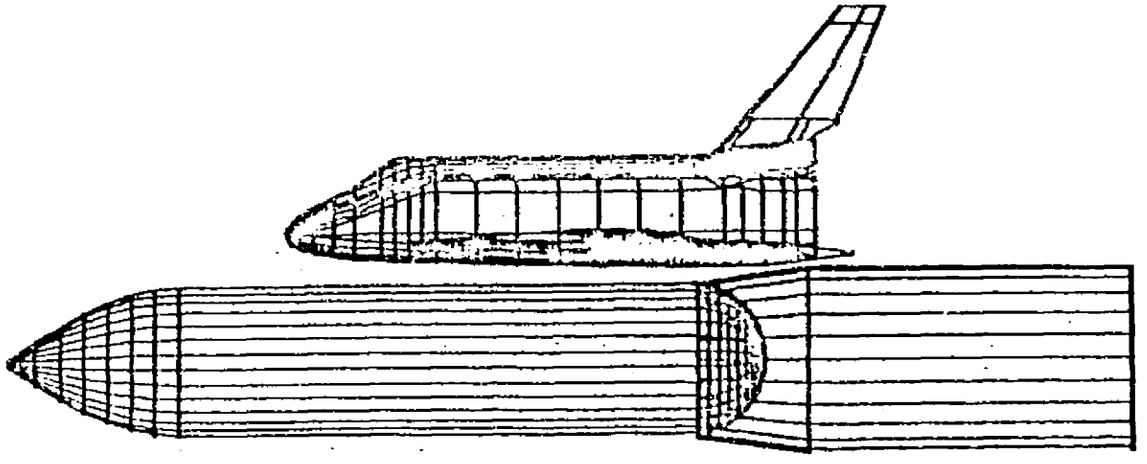

EDIN0504 REENTRY HEATING DEC 75
HEAT
REYN
H RATE
TIME
X10 1
X10 10

EDIN0504B DESIGN

SIMULATION RESULTS

```
**********************************************************************
FORECASTER: EDIN DESIGN CENTER                        DATE: 3 DEC 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION-JSC        TIME: 15:06
STUDY NO: EDINS04
**********************************************************************

.
CONCEPT:      A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 3.000 F-1
              ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR REPLACEMENT
              OF THE SOLID ROCKET BOOSTERS.

.
MISSION:      MAXIMUM PAYLOAD
              DUE EAST LAUNCH FROM ETR
              A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL
              MILE REFERENCE ORBIT.
              A 100 FPS RCS TRANSLATION DELTA VEL.

.
TRAJECTORY:   DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH
              PROFILE AND INITIAL TILT RATE.
                 MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS-ROR
                 END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO
              ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY ONE F1
              ENGINE SHUTDOWN AND-OR SOME THROTTLING.
                 MAX DYNAMIC PRESSURE = 650.0 PSF
                 MAX ACCELERATION     = 3.0 G

.
PROPULSION:   LRB: 3.000 F-1 ENGINES RATED AS FOLLOWS:
                 THRUST(SL)  = 1606798.9 LBS
                 THRUST(VAC) = 1748060.0  LBS
                 ISP(SL)     = 266.01 SEC.
                 ISP(VAC)    = 289.40 SEC.
                 FLOWRATE    = 6040.3 LB-SEC
                 EXIT AREA   = 66.763 SQ FT
                 MIX RATIO   = 2.27:1
              ORBITER: THREE SSME ENGINES RATED AT FOLLOWS:
                 THRUST(SL)  = 375000.00 LBS
                 THRUST(VAC) = 470000.00 LBS
                 THROTTLE    = 1.09 TO .500
                 ISP(SL)     = 363.20 SEC
                 ISP(VAC)    = 455.20 SEC
                 FLOWRATE    = 1032.5 LB-SEC
                 EXIT AREA   = 44.896 SQ FT
                 MIX RATIO   = 6.00:1

.
AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION
              WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS
              WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
                 REF AREA    = 2557.0 SQ FT

.
STRUCTURE:    ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS
              ARE INCLUDED FOR DELETION OF THE SRB-ET ATTACHMENTS AND
              INCREASED UP PAYLOADS.

.
MASS          MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC
PROPERTIES:   ASSUMPTIONS.
                 LRB: WERE BASED ON SATURN TECHNOLOGY.
                 ET: FIXED MASS FRACTION DISTRIBUTED IN
                     ACCORDANCE WITH SHUTTLE ET WEIGHT
                     STATEMENT.
                 ORBITER: FEB 1975 SHUTTLE WITH MODS FOR
                     INCREASED UP PAYLOAD.
```

EDIN0504B DESIGN SIMULATION RESULTS



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.                        WEIGHTS SUMMARY REPORT
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.
GLOW                                                        4598410.00
.
ET LIFT-OFF WEIGHT                                          1904993.30
.
   ET INERT WEIGHT                      103931.97
   ET PROPELLANT                       1801061.36
.
LRB LIFT-OFF WEIGHT                                         2427663.00
.
   LRB INERT WEIGHT                     247799.73
   LRB PROPELLANT                      2179863.00
.
ORBITER LIFT-OFF WEIGHT                                      265754.00
.
   ORBITER INERT WEIGHT                 187254.00
   PAYLOAD                               78500.00
.
.
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ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2862.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	19874.	
LANDING & PUR SYSTEMS	7683.	
PROPULSION-ASCENT	38054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2923.	
ELECTRICAL CONVERSION	6960.	
HYDR. LIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5775.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 100K PAYLD	390.	
ORBITER EMPTY WEIGHT		151715.
PERSONNEL	6644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1640.	
INFLIGHT LOSSES	3171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	19149.	
ORBITER INERT WEIGHT		187654.
PAYLOAD		75500.
ORBITER PRELAUNCH WEIGHT		265754.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		17151.
BHD	84.	
FWD FRAME	54.	
FWD OGIVE	1415.	
AFT OGIVE	4758.	
XT 745 FRAME	330.	
BARREL	3077.	
INTERTANK FRAME	1123.	
AFT DOME	3659.	
SLOSH BAFFLES	2651.	
INTERTANK		13404.
MACHINED BARREL PNLS	5367.	
IK/STGR BARREL PNLS	5801.	
STABILIZING FRAMES(4)	1567.	
SRB THRST XT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	72.	
BARREL PNLS SPLICES (8)	119.	
FRAME STABLIZERS	257.	
ET ASSY FASTENERS	201.	

LH2 TANK		42075.
FWD DOME	2006.	
MT 1129.9 FRAME	1980.	
BARREL NO.4	6882.	
MT 1377 FRAME	691.	
BARREL NO.3	6919.	
MT 1624 FRAME	691.	
BARREL NO.2	6923.	
MT 1871 FRAME	2168.	
BARREL NO.1	7328.	
MT 2058 FRAME	4145.	
AFT DOME	3347.	
THERMAL PROTECTION		8153.
LOX TANK	1748.	
INTERTANK	1815.	
LH2 TANK	4258.	
PROP (MECH+ELEC)	332.	
PROPULSION AND MECHANICAL SYSTEMS		4750.
LOX FEED SYS	2031.	
LOX PNTIGEYER SYS	191.	
LOX VENT SYS	107.	
LOX PRESS. SYS	231.	
LH2 FEED SYS	581.	
LH2 RECIR. SYS	38.	
LH2 VENT SYS	162.	
LH2 PRESS. SYS	171.	
HELIUM INJ. SYS	26.	
INTERTANK PURGE SYS	101.	
HAZARD GAS DETECTION SYS	10.	
FAIRINGS AND CONDUIT	429.	
LINE SUPTS. AND ATTACHS.	672.	
ELECTRICAL SYSTEM		294.
ET WIRING ASSY	198.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	18.	
CABLING ATTACHS.+SENSOR SUPTS.	77.	
ORB/SRB ATTACHMENTS		5651.
ORBITER SUPPORTS	3878.	
UMBILICAL BEAM	795.	
ORB/ET ATTACH FTGS	295.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	683.	
MANUFACTURING VARIATION WT.		534.
EMPTY WEIGHT		92012.
UNUSABLE FLUIDS		513.
LH2 IN TANK	258.	
LH2 IN LINE	59.	
LOX IN LINE	166.	
PRE-PRESS.+INFLIGHT GASES		4647.
GH2	1208.	
GOX	3400.	
HELIUM	39.	
SEPARATION HARDWARE		6.
SRB SUPPORTS	0.	
ORB FITTINGS	6.	
FLT PERF RES		6754.
ET INERT WT		103932.
MAIN PROPELLANTS		1801061.
LOX	1543767.	
LH2	257294.	
ET LIFT-OFF WEIGHT		1904993.
MASS FRACTION (BASED ON INERT WEIGHT		.94544

LIQUID ROCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		83476.
INTEGRAL LOX TANK	19912.	
INTEGRAL FUEL TANK	13203.	
INTERSTAGE	6583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	36718.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		2136.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1195.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		766.
ELECTRICAL SYSTEM	655.	
CONTROL SYSTEM	110.	
INSTRUMENTATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		97631.
ENGINES (DRY)	57114.	
ACCESSORIES	416.	
GIMBAL SYSTEM	5833.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	8389.	
OXIDIZER SYSTEM	12073.	
SEPARATION AND RECOVERY SYSTEM		15644.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	5086.	
FLOATATION SYSTEM	92.	
RECOVERY AIDS	91.	
FITTINGS AND SUPPORTS	175.	
RETRO SYS (100 F/S DEL V)	2825.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		208069.
CONTINGENCY		0.
EMPTY WEIGHT		208069.
PROPELLANT RESIDUALS		35899.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	3709.	
TRAPPED FUEL TANK GASES	2994.	
FROST TRAPPED	401.	
TRAPPED FUEL	11379.	
TRAPPED LOX	15723.	
IN-FLIGHT LOSSES		3752.
FUEL LOSSES	1813.	
LOX LOSSES	1939.	
LRB INERT WT		247740.
MAIN PROPELLANTS		2179923.
FUEL	666643.	
LOX	1513280.	
BLOW		2427663.
MASS FRACTION (BASED ON INERT WT)		.8980

ORBITER WT	265754.0
ET WEIGHT	1904993.4
LRB WEIGHT	2427663.0
GLOW	4598410.4
STG 1 LAMBDA	.91153
STG 2 LAMBDA	.93217

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CONVERGENCE DATA:
       GLOW                                          4588410.
          ACTUAL PAYLOAD                                          79528.
       TOTAL VIDEAL                                   30956.7
          STAGE 1 VIDEAL                                        7791.6
          STAGE 2 VIDEAL                                       23165.1
       TOTAL PROPELLANT                              3950946.
          LRB PROPELLANT                                       21,9981.
          ET PROPELLANT                                        1801425.
       STAGE JETTISON WEIGHTS
          STAGE 1 JETTISON WT                                   347740.
          STAGE 2 JETTISON WT                                   103938.

 STAGE 1 SIZING DATA
       AVERAGE SP. IMP.                                298.99
       LIFT-OFF T/W                                      1.308
       MAXIMUM Q                                        649.6
       TIME AT MAX Q                                     71.0
       STG 1 MAX LF                                      3.00
       TIME AT MAX LF                                   114.0
       EFF WDOT/LRB                                   18120.9
       EFF WDOT/EVENT 1                               21219.5

 STAGING CONDITIONS:
       WEIGHT                                        2045720.
       REL VELOCITY (FPS)                              4250.7
       REL F.P. ANGLE (DEG)                              28.15
       ALTITUDE (FT)                                  113461.
       TIME (SEC)                                       120.30
       ATT AFTER STG (DEG)                                .94
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MISSION SUMMARY: DECEMBER 8, 1975

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PARAMETER	EVENT 1	EVENT 2	EVENT 3	EVENT 4
TIME (SEC)	120.3	309.6	568.4	451.2
ALTITUDE (K FT)	113.5	349.0	396.4	0
REL VELOCITY (100 FPS)	42.5	81.4	243.1	2.072
REL GAMMA (DEG)	28.1	8.29	.552	-89.8
WEIGHT (K LBS)	4598.4	1798.0	1158.7	247.7
WEIGHT DROP (K LBS)	247.7	0	103.9	0
THROW WEIGHT (K LBS)	1798.0	1158.7	265.78	0
CUM VIDEAL (100 FPS)	77.92	142.3	309.6	0
DOWNRANGE (NMI)	20.87	225.8	918.5	223.0

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EVENT 1 BECO/SEPARATION EVENT 3 MECO/INJECTION
EVENT 2 RTLS-AOA CONSTRAINT EVENT 4 LRB TOUCHDOWN

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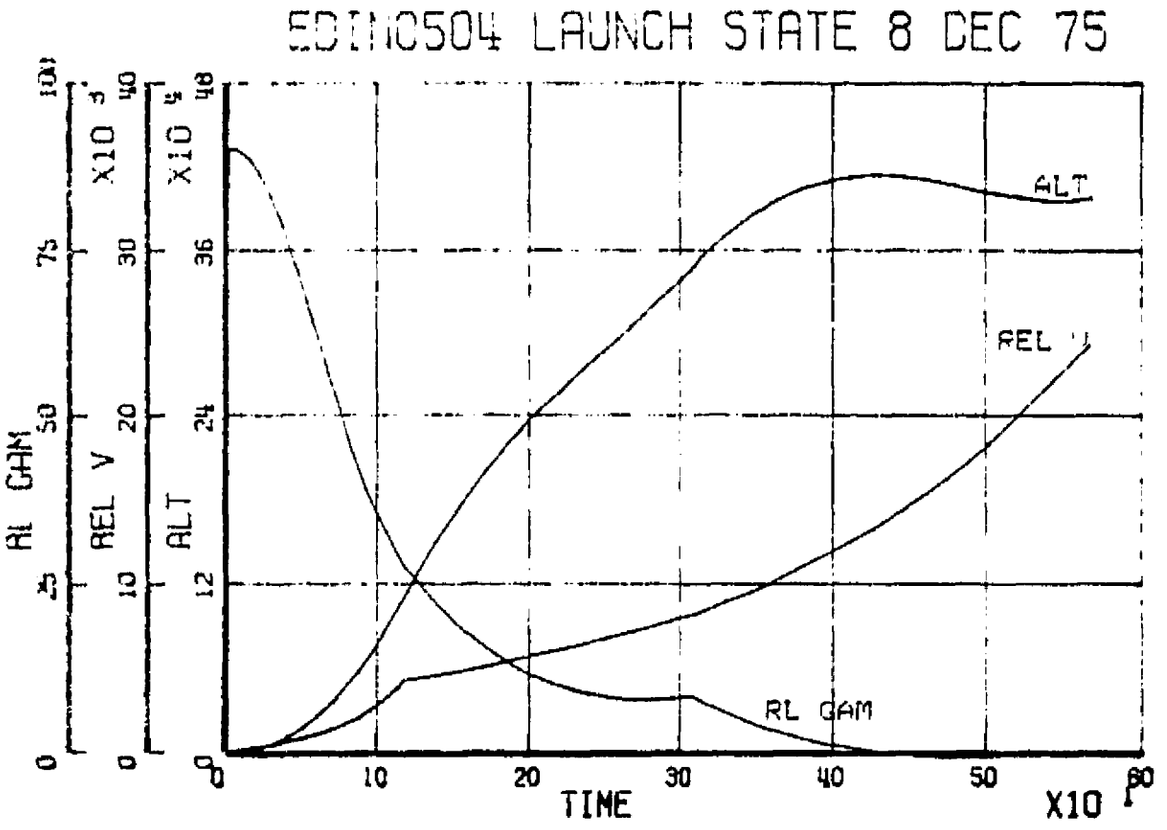
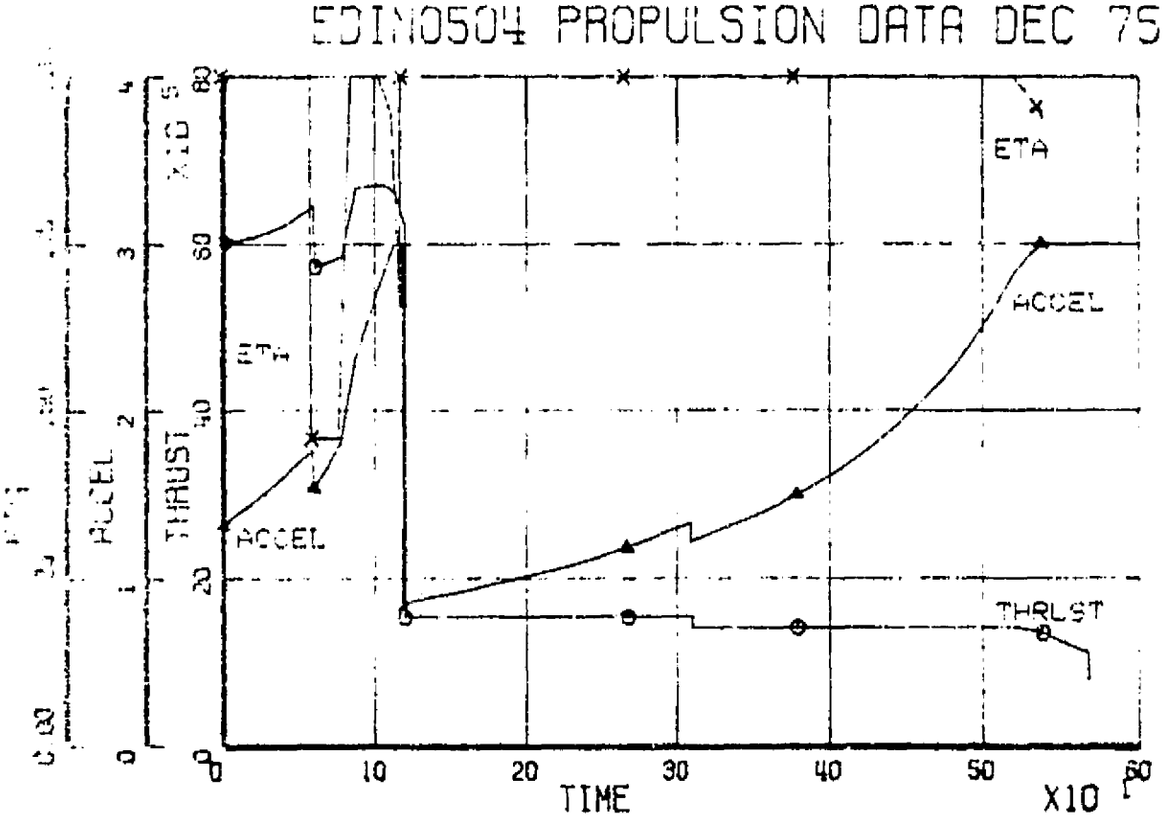
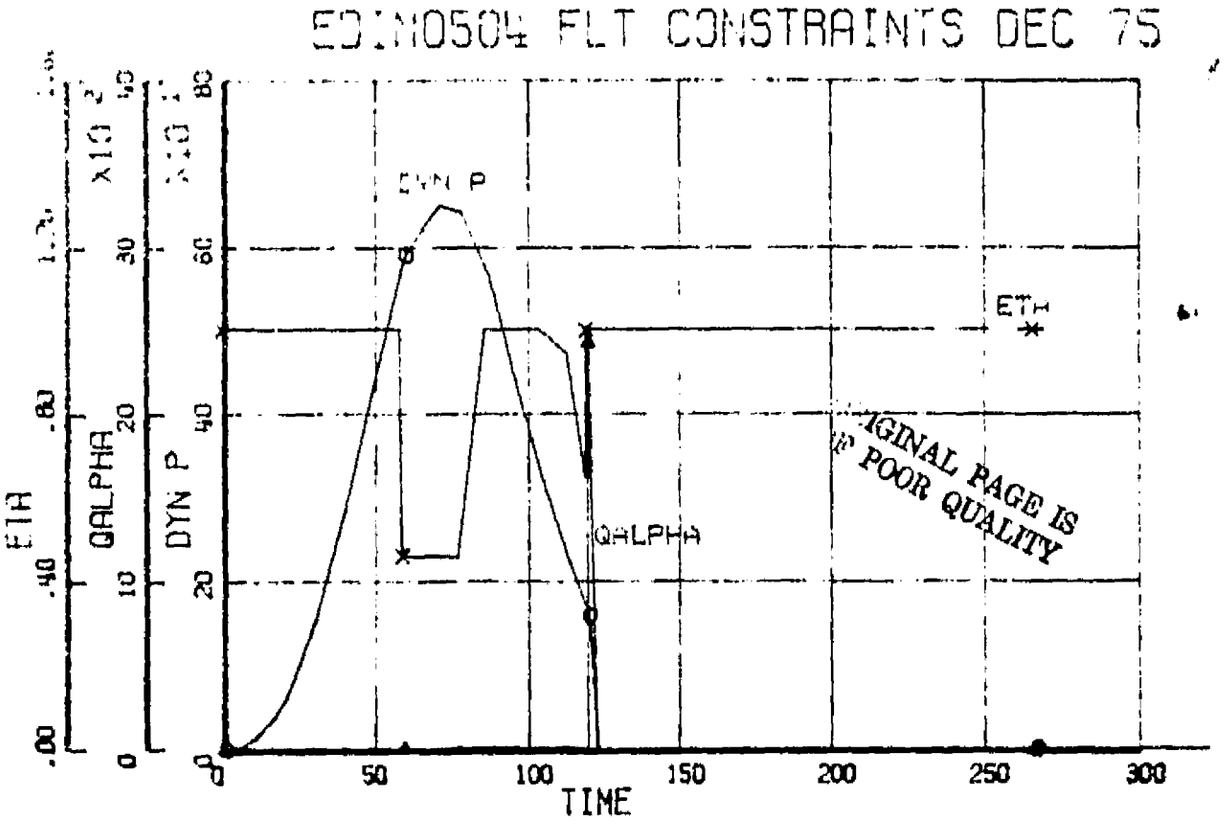
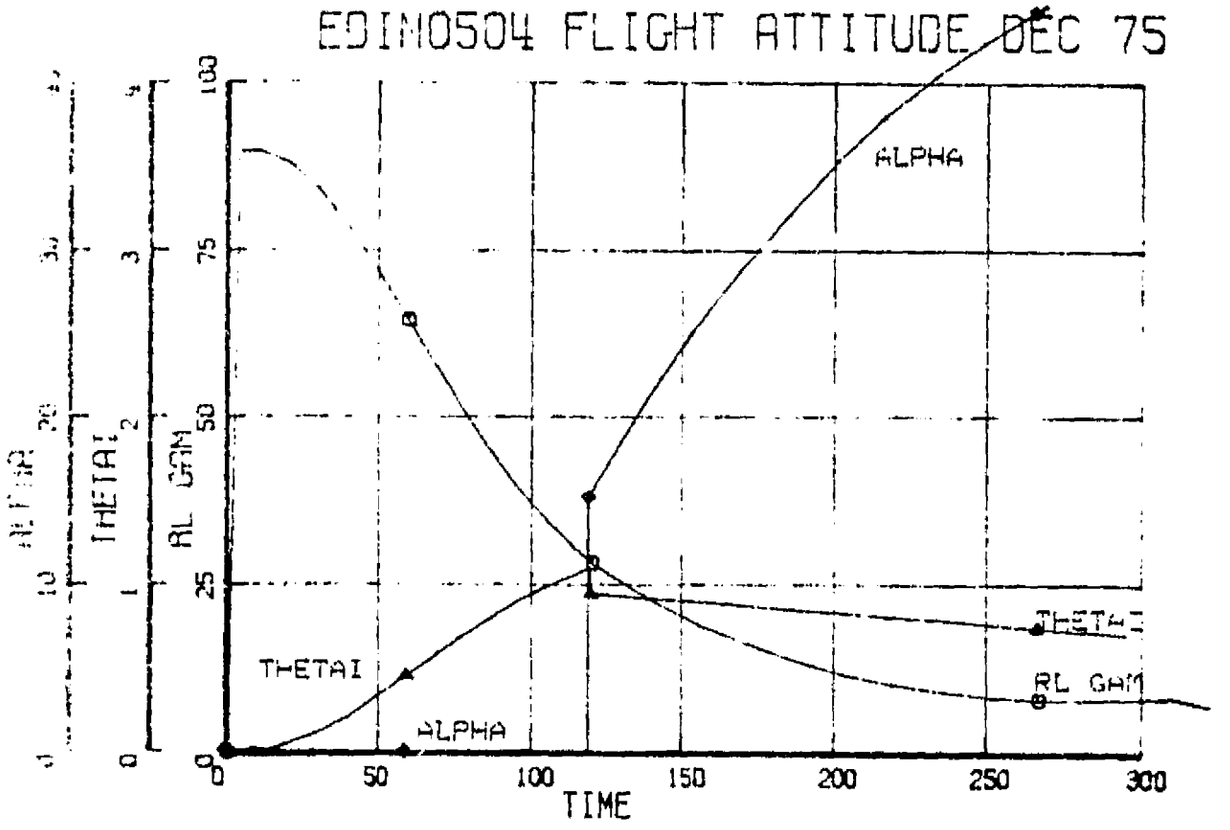
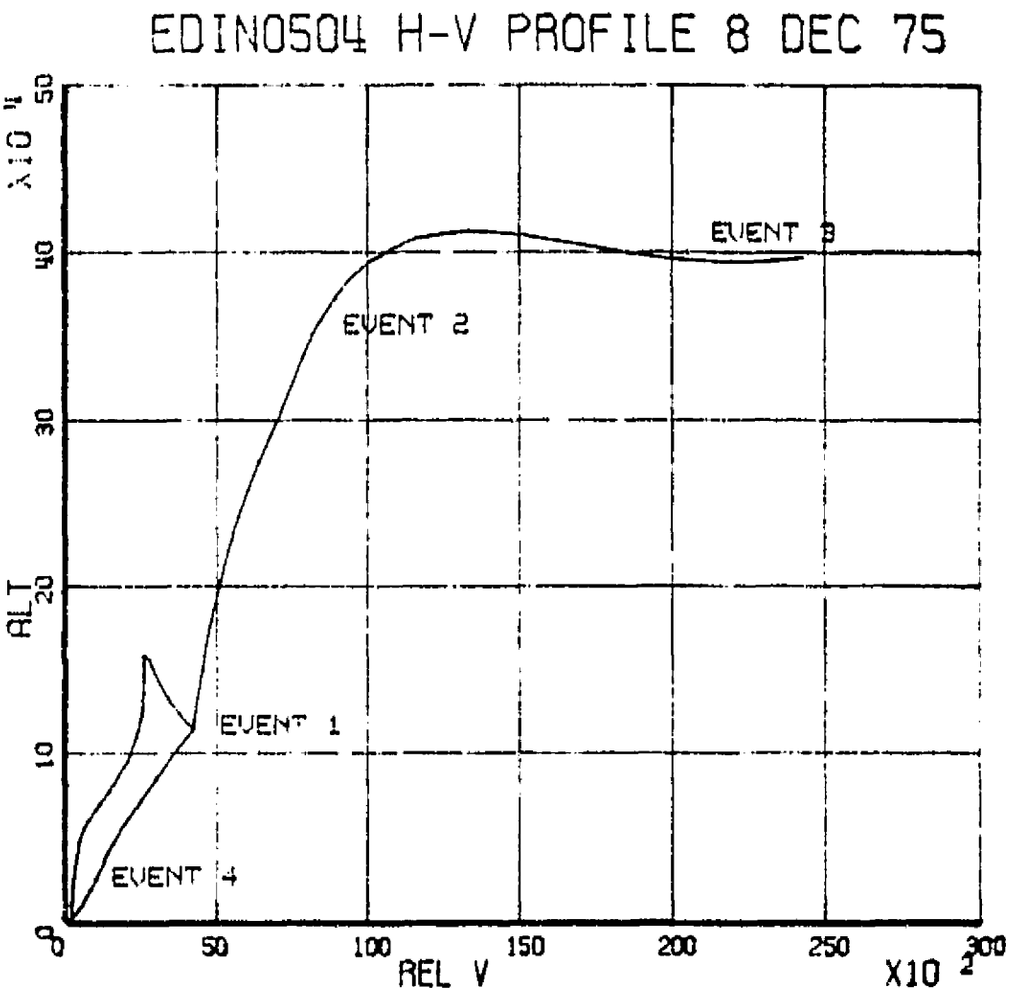
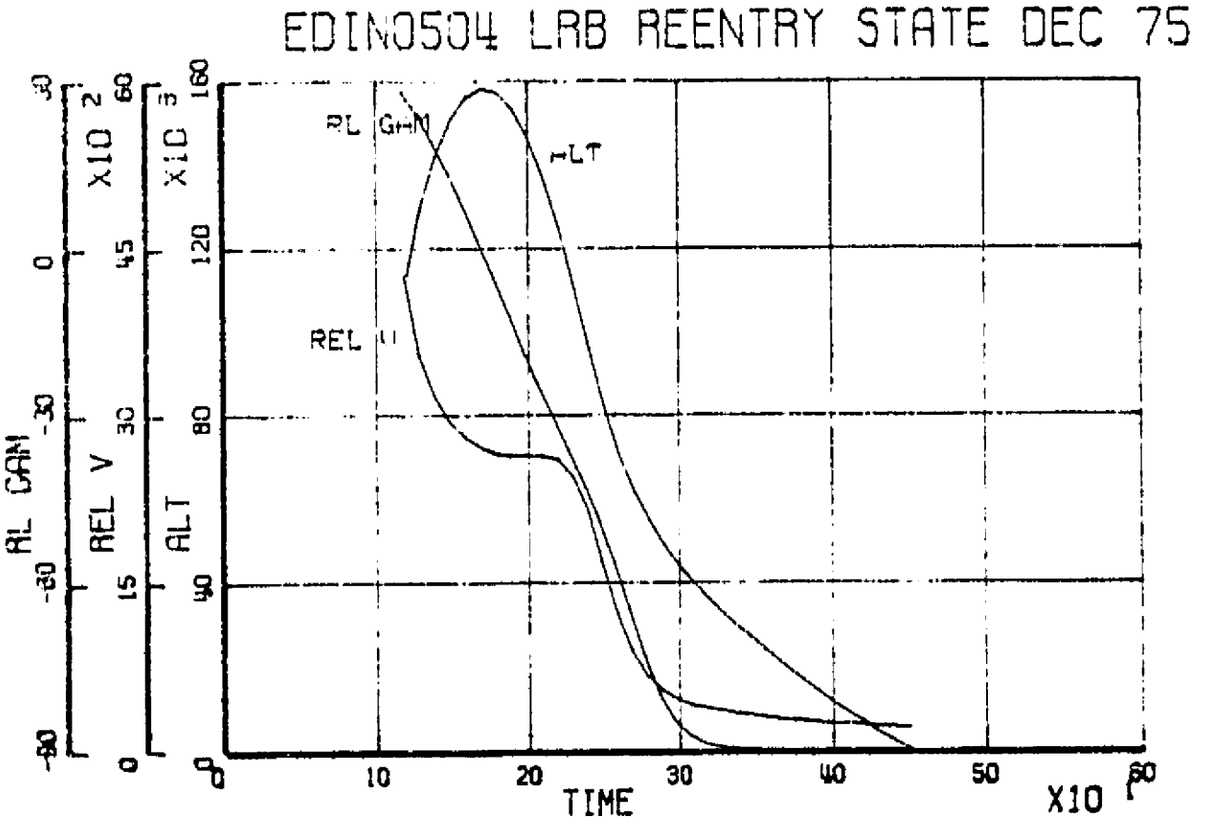

EDIN0504 LAUNCH STATE 8 DEC 75
RL GAM
REL V
X10 3
ALT
X10 4
ALT
REL V
RL GAM
TIME
X10

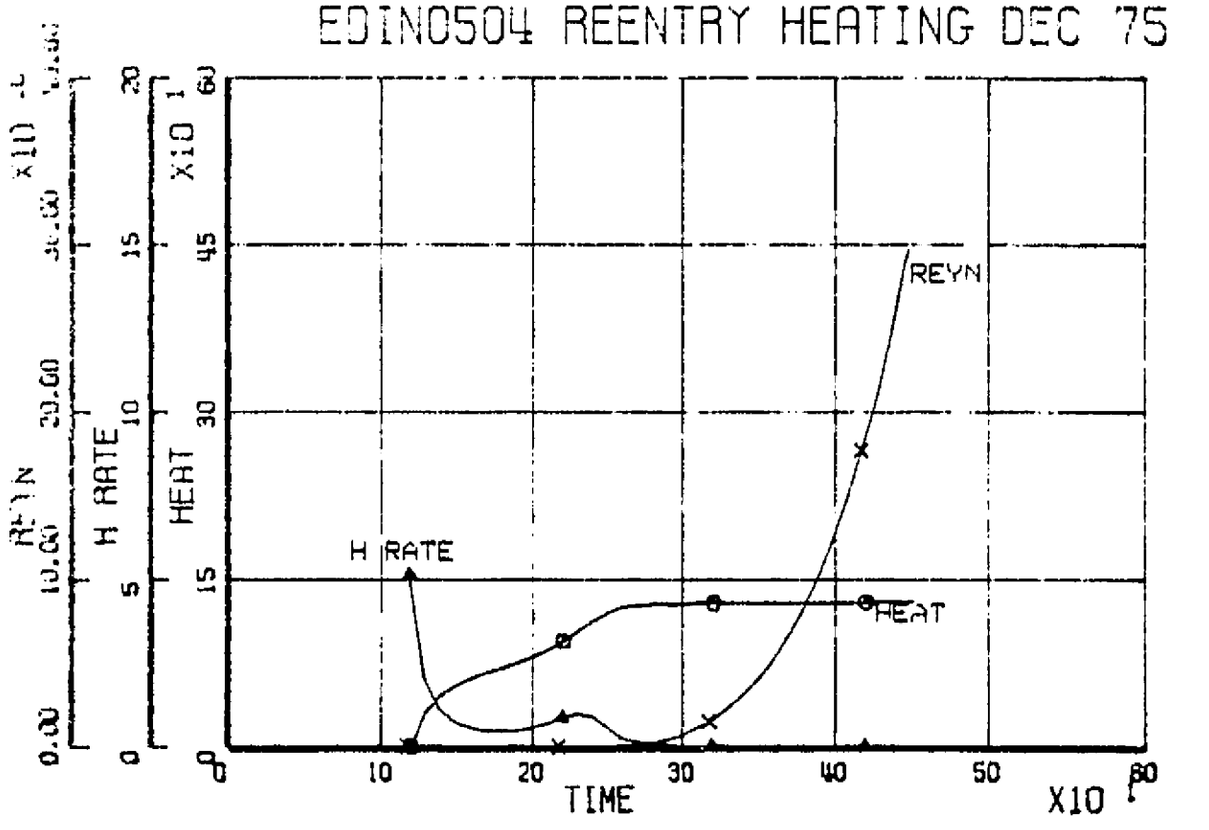

EDIN0504 PROPULSION DATA DEC 75
ACCEL
THRUST
X10 5
ETA
ACCEL
THRUST
TIME
X10






EDIN0504 H-V PROFILE 8 DEC 75
ALT X10 4
0
10
20
30
40
50
0
50
100
150
200
250
300
REL V
X10 2
EVENT 1
EVENT 2
EVENT 3
EVENT 4


EDIN0504 LRB REENTRY STATE DEC 75
REL GAM
ALT
REL V
TIME
X10


EDIN0504 REENTRY HEATING DEC 75
REYN
H RATE
HEAT
TIME
X10

EDIN0504C DESIGN

SIMULATION RESULTS

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◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
FORECASTER: EDIN DESIGN CENTER                          DATE: 9 DEC 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC          TIME: 13:30
STUDY NO: EDIN0504
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

.
CONCEPT:      A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 7.71 HIGH
              PRESSURE ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR
              REPLACEMENT OF THE SOLID ROCKET BOOSTERS.

.
MISSION:      150000.0 LB PAYLOAD
              DUE EAST LAUNCH FROM ETR
              A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL
              MILE REFERENCE ORBIT.
              A 100 FPS RCS TRANSLATION DELTA VEL.

.
TRAJECTORY:   DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH
              PROFILE AND INITIAL TILT RATE.
                 MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS-ABA
                 END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO
              ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY HIGH
              PRESSURE ENGINE THROTTLING AND/OR SIME THROTTLING.
                 MAX DYNAMIC PRESSURE = 650.0 PSF
                 MAX ACCELERATION     = 3.0 G

.
PROPULSION:   LRB: 7.71 HIGH PRESSURE ENGINES RATED AS FOLLOWS:
                 THRUST(SL)  = 900000.00 LBS
                 THRUST(VAC) = 986293.00  LBS
                 THROTTLE    = 1.00 TO .500
                 ISP(SL)     = 321.00 SEC.
                 ISP(VAC)    = 347.60 SEC.
                 FLOWRATE    = 2492.2 LB/SEC
                 EXIT AREA   = 32.000 SQ FT
                 MIX RATIO   = 2.50:1
              ORBITER: THREE SSME ENGINES RATED AS FOLLOWS:
                 THRUST(SL)  = 375000.00 LBS
                 THRUST(VAC) = 470000.00 LBS
                 THROTTLE    = 1.09 TO .500
                 ISP(SL)     = 363.20 SEC
                 ISP(VAC)    = 455.20 SEC
                 FLOWRATE    = 1032.5 LB/SEC
                 EXIT AREA   = 44.896 SQ FT
                 MIX RATIO   = 6.00:1

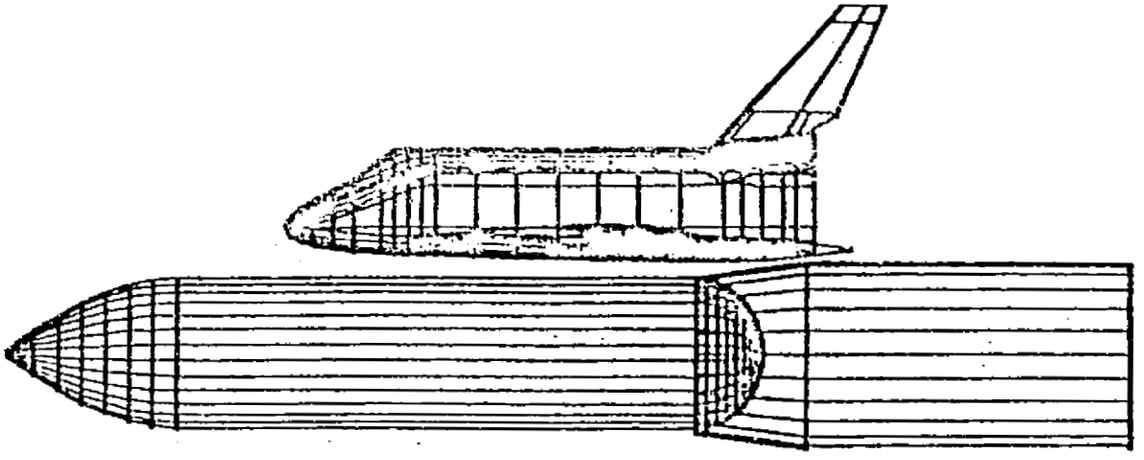
.
AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION
              WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS
              WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
                 REF AREA    = 2557.0 SQ FT

◆TB◆DEMAND SUPPORT ENDS IN 25 MINUTES ◆◆◆◆◆◆◆◆

.
STRUCTURE:    ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS
              ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND
              INCREASED UP PAYLOADS.

.
MASS          MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC
PROPERTIES:   ASSUMPTIONS.
                 LRB: WERE BASED ON SATURN TECHNOLOGY.
                 ET: FIXED MASS FRACTION DISTRIBUTED IN
                     ACCORDANCE WITH SHUTTLE ET WEIGHT
                     STATEMENT.
                 ORBITER: FEB 1975 SHUTTLE WITH MODS FOR
                     INCREASED UP PAYLOAD.
```

EDIN0504C DESIGN SIMULATION RESULTS



WEIGHTS SUMMARY REPORT

GLOW		4586902.56
ET LIFT-OFF WEIGHT		1351372.48
ET INERT WEIGHT	75160.791	
ET PROPELLANT	1276212.00	
LRB LIFT-OFF WEIGHT		2897716.25
LRB INERT WEIGHT	255852.27	
LRB PROPELLANT	2641864.00	
ORBITER LIFT-OFF WEIGHT		337814.00
ORBITER INERT WEIGHT	187314.00	
PAYLOAD	150000.00	

ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2852.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	13874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	22054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2329.	
ELECTRICAL CONVERSION	2260.	
HYDRAULIC CONVERSION	1340.	
SURFACE CONTROLS	2733.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 150K PAYLD	950.	
ORBITER EMPTY WEIGHT		152275.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1540.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16148.	
ORBITER INERT WEIGHT		187814.
PAYLOAD		150000.
ORBITER PRELAUNCH WEIGHT		337814.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		12153.
BHD	59.	
FWD FRAME	38.	
FWD OGIVE	1003.	
AFT OGIVE	3372.	
XT 745 FRAME	234.	
BARREL	2180.	
INTERTANK FRAME	796.	
AFT DOME	2593.	
SLOSH BAFFLES	1379.	
INTERTANK		9438.
MACHINED BARREL PNLS	3803.	
SK/STGR BARREL PNLS	4111.	
STABILIZING FRAMES(4)	1125.	
SRB THRST XT 925 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	51.	
BARREL PNLS SPLICES (8)	84.	
FRAME STABLIZERS	182.	
ET ASSY FASTENERS	142.	

LH2 TANK		29514.
FWD DOME	1422.	
FT 1129.9 FRAME	1403.	
BARREL NO.4	4877.	
FT 1377 FRAME	489.	
BARREL NO.3	4903.	
FT 1624 FRAME	489.	
BARREL NO.2	4905.	
FT 1871 FRAME	1537.	
BARREL NO.1	5198.	
FT 2058 FRAME	2937.	
AFT DOME	1663.	
THERMAL PROTECTION		5777.
LOX TANK	1239.	
INTERTANK	1286.	
LH2 TANK	3017.	
PROP (MECH+ELEC)	235.	
PROPULSION AND MECHANICAL SYSTEMS		3366.
LOX FEED SYS	1439.	
LOX ANTIGEYER SYS	135.	
LOX VENT SYS	76.	
LOX PRESS. SYS	164.	
LH2 FEED SYS	412.	
LH2 RECIR. SYS	27.	
LH2 VENT SYS	115.	
LH2 PRESS. SYS	121.	
HELIUM INJ. SYS	19.	
INTERTANK PURGE SYS	71.	
HAZARD GAS DETECTION SYS	7.	
FAIRINGS AND CONDUIT	304.	
LINE SUPTS. AND ATTACHS.	476.	
ELECTRICAL SYSTEM		206.
ET WIRING ASSY	141.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	13.	
CABLING ATTACHS.+SENSOR SUPTS.	55.	
ORB/SRB ATTACHMENTS		4004.
ORBITER SUPPORTS	2748.	
UMBILICAL BEAM	563.	
ORB/ET ATTACH FTGS	209.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	484.	
MANUFACTURING VARIATION WT.		378.
EMPTY WEIGHT		65199.
UNUSABLE FLUIDS		364.
LH2 IN TANK	204.	
LH2 IN LINE	42.	
LOX IN LINE	117.	
PRE-PRESS.+INFLIGHT GASES		3893.
GH2	856.	
GOX	2409.	
HELIUM	28.	
SEPARATION HARDWARE		4.
SRB SUPPORTS	0.	
ORB FITTINGS	4.	
FLT PERF RES		6301.
ET INERT WT		75161.
MAIN PROPELLANTS		1276212.
LOX	1093896.	
LH2	182316.	
ET LIFT-OFF WEIGHT		1351373.
MASS FRACTION (BASED ON INERT WEIGHT		.94438

LIQUID ROCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		103821.
INTEGRAL LOX TANK	22433.	
INTEGRAL FUEL TANK	13812.	
INTERSTAGE	8583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	42833.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		3333.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1281.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		820.
ELECTRICAL SYSTEM	702.	
CONTROL SYSTEM	118.	
INSTRUMENTATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		77304.
ENGINES (DRY)	48981.	
ACCESSORIES	357.	
GIMBAL SYSTEM	4531.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	7312.	
OXIDIZER SYSTEM	11668.	
SEPARATION AND RECOVERY SYSTEM		15667.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	5785.	
FLOTATION SYSTEM	104.	
RECOVERY AIDS	102.	
FITTINGS AND SUPPORTS	197.	
RETRO SYS (100 F/S DEL V)	3174.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		209170.
CONTINGENCY		0.
EMPTY WEIGHT		209170.
PROPELLANT RESIDUALS		42212.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	4139.	
TRAPPED FUEL TANK GASES	3388.	
FROST TRAPPED	454.	
TRAPPED FUEL	12764.	
TRAPPED LOX	19606.	
IN-FLIGHT LOSSES		4471.
FUEL LOSSES	2053.	
LOX LOSSES	2418.	
LRB INERT WT		255853.
MAIN PROPELLANTS		2641564.
FUEL	754818.	
LOX	1887046.	
BLOW		2897716.
MASS FRACTION (BASED ON INERT WT)		.91171

ORBITER WT	337814.0
ET WEIGHT	1351372.5
LRB WEIGHT	2897716.2
GLOW	4586902.7
STG 1 LAMBDA	.91171
STG 2 LAMBDA	.94436

```
CONVERGENCE DATA:
      GLOW                                          4536403.
      TARGET PAYLOAD                                 150000.
         ACTUAL PAYLOAD                                        150388.
      TOTAL VIDEAL                                   30005.5
         STAGE 1 VIDEAL                                         9388.4
         STAGE 2 VIDEAL                                        20617.1
      TOTAL PROPELLANT                              3917684.
         LRB PROPELLANT                                       2641820.
         ET PROPELLANT                                        1275864.
      STAGE JETTISON WEIGHTS
         STAGE 1 JETTISON WT                                   355858.
         STAGE 2 JETTISON WT                                    75161.

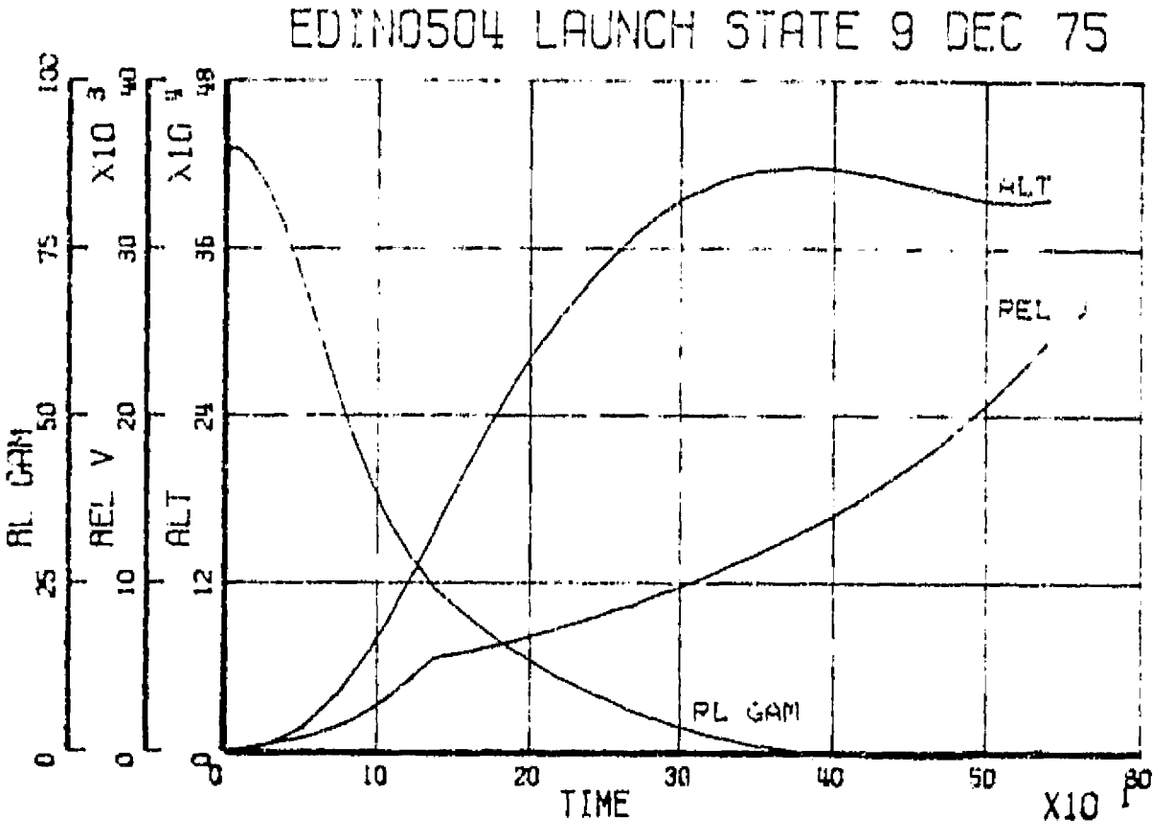
STAGE 1 SIZING DATA
      AVERAGE SP. IMP.                                340.13
      LIFT-OFF T/W                                     1.345
      MAXIMUM Q                                        650.3
      TIME AT MAX Q                                     73.3
         MAX LF                                         3.00
      TIME AT MAX LF                                   125.0
      WEIGHT/LRB                                     19087.9
      WEIGHT/EVENT 1                                 19087.9

STAGING CONDITIONS:
      WEIGHT                                        1945083.
      REL VELOCITY (FPS)                              5556.9
      REL F.P. ANGLE (DEG)                              24.66
      ALTITUDE (FT)                                  158036.
      TIME (SEC)                                      138.40
      ATT AFTER STG (DEG)                                .95
```


MISSION SUMMARY: DECEMBER 9, 1975

PARAMETER	EVENT 1	EVENT 2	EVENT 3	EVENT 4
TIME (SEC)	138.4	250.1	541.5	522.1
ALTITUDE (K FT)	158.0	348.6	394.4	0
REL VELOCITY (100 FPS)	55.6	81.4	243.0	2.107
REL GAMMA (DEG)	24.7	8.27	.528	-89.8
WEIGHT (K LBS)	4586.9	1689.2	1312.0	255.9
WEIGHT DROP (K LBS)	255.9	0	75.16	0
THROW WEIGHT (K LBS)	1689.2	1312.0	938.20	0
CUM VIDEAL (100 FPS)	93.68	130.9	300.1	0
DOWNRANGE (NMI)	34.48	167.8	938.9	192.5

EVENT 1 BECO/SEPARATION
EVENT 2 ATLS/ADA CONSTRAINT
EVENT 3 MECO/INJECTION
EVENT 4 LRB TOUCHDOWN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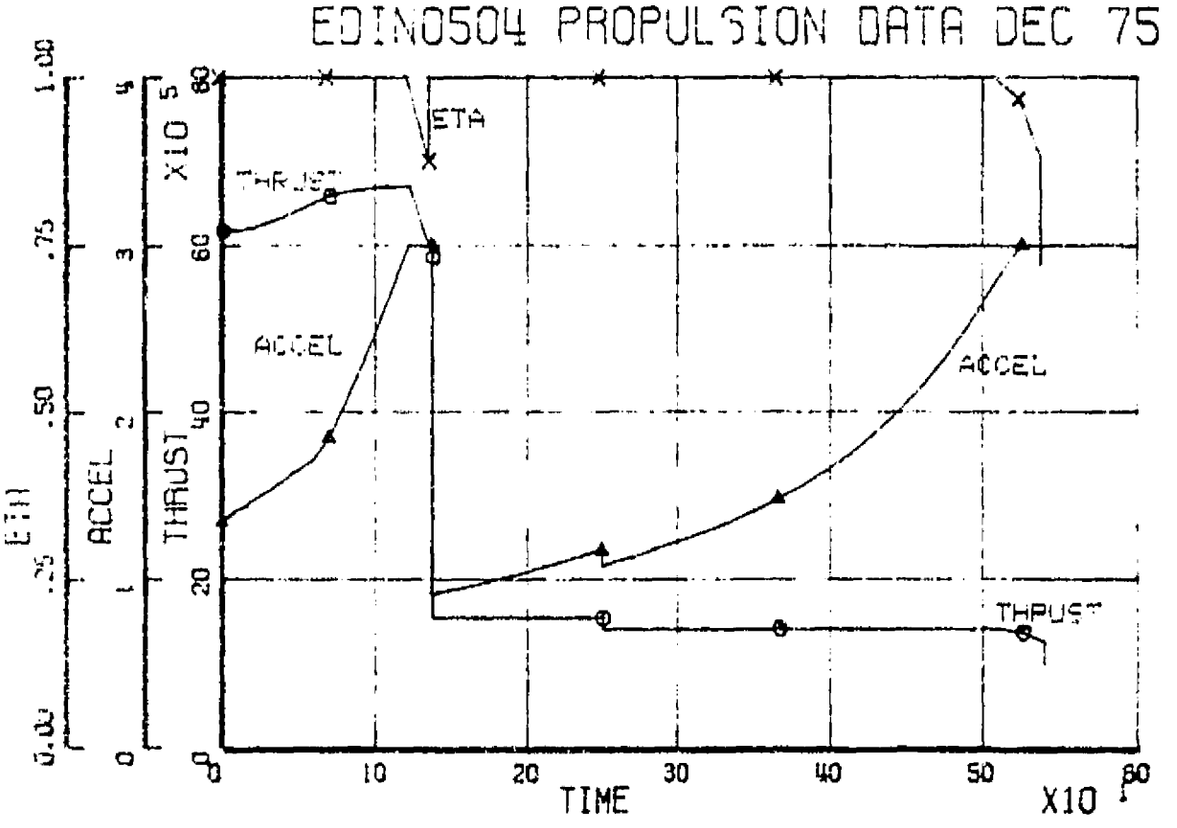
RL GAM
REL V
X10 3
ALT
X10 4
ALT
REL V
RL GAM
TIME
X10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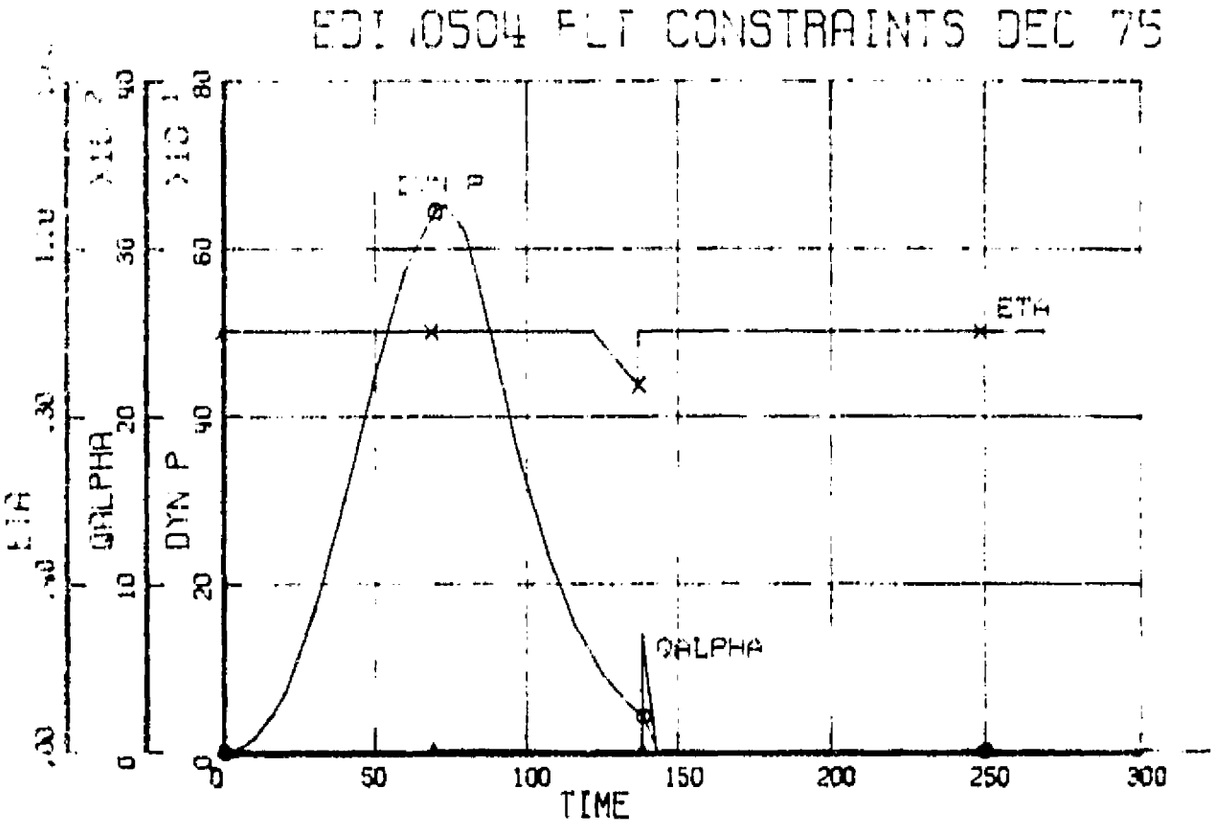
ETA
ACCEL
THRUST
X10 5
ACCEL
THRUST
ACCEL
THRUST
TIME
X10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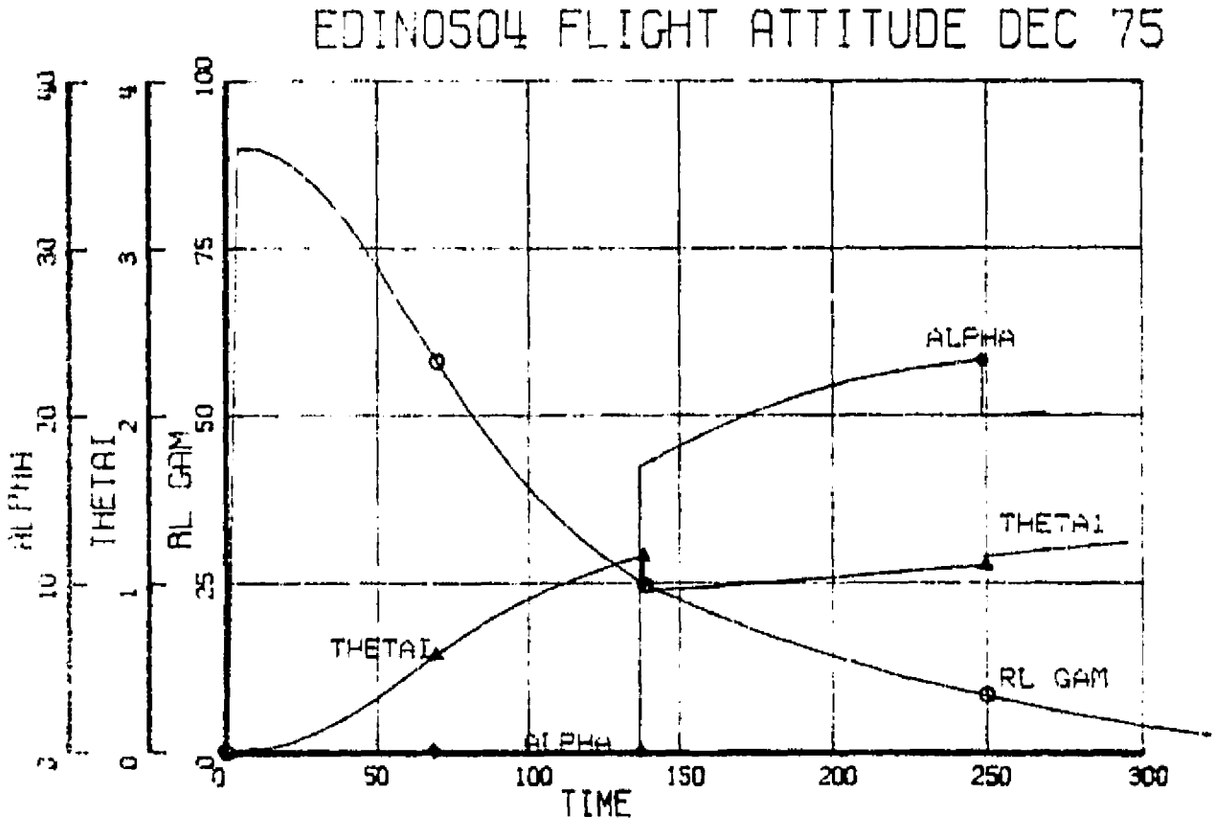
ETH
QALPHA
DYN P
TIME
0
50
100
150
200
250
300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ALPHA
THETA1
RL GAM
TIME
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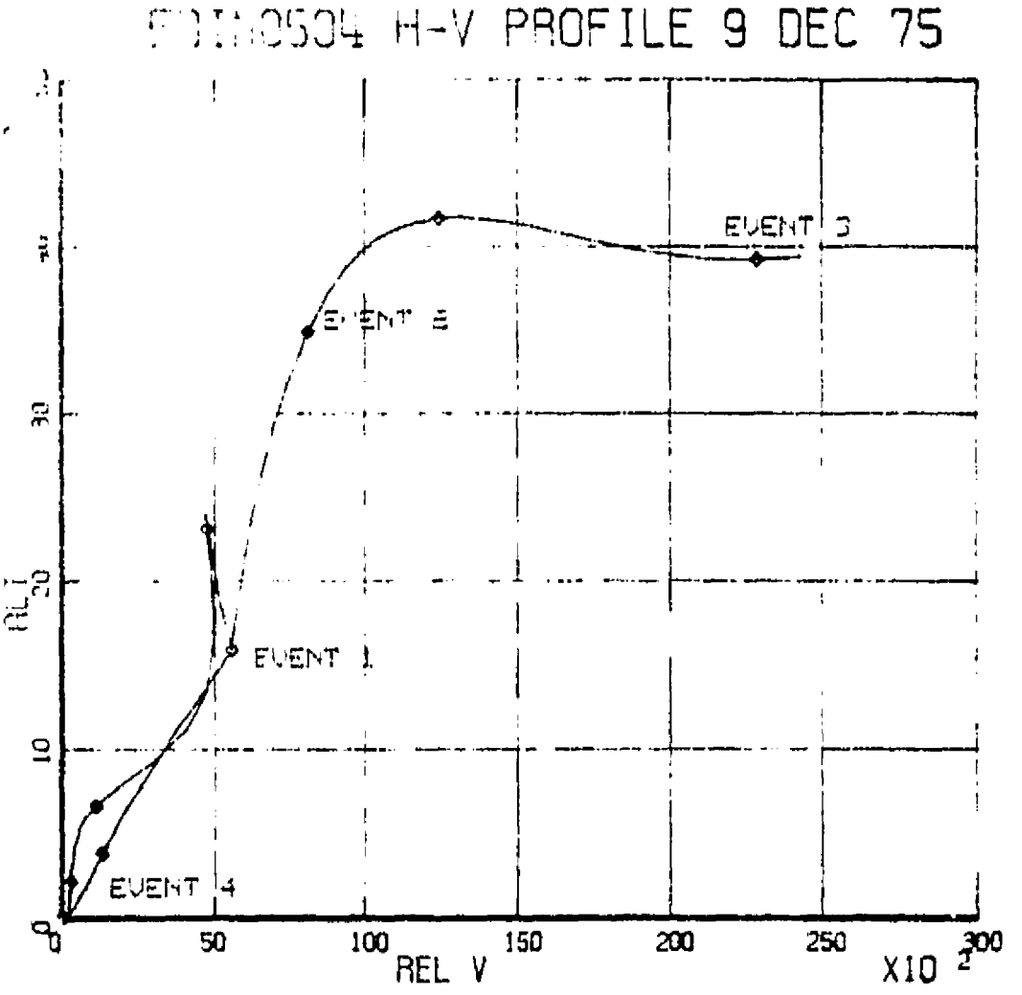
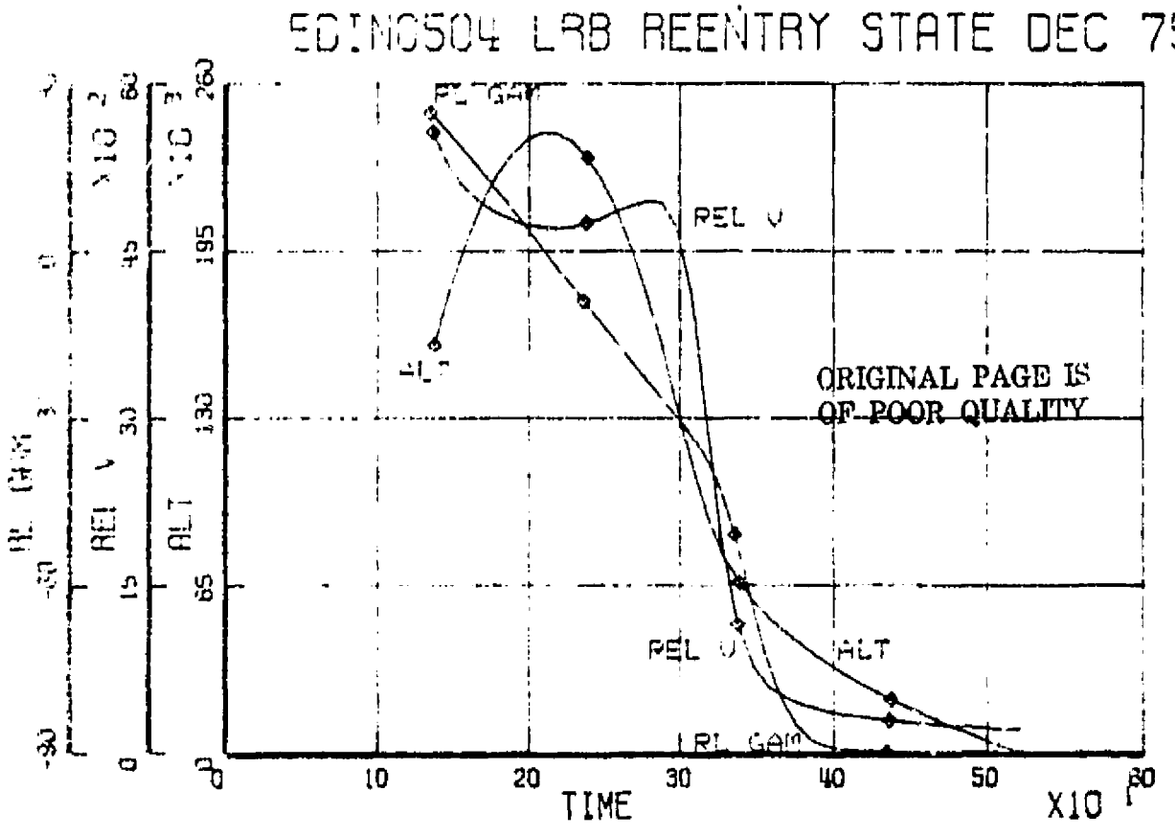
50
100
150
200
250
300

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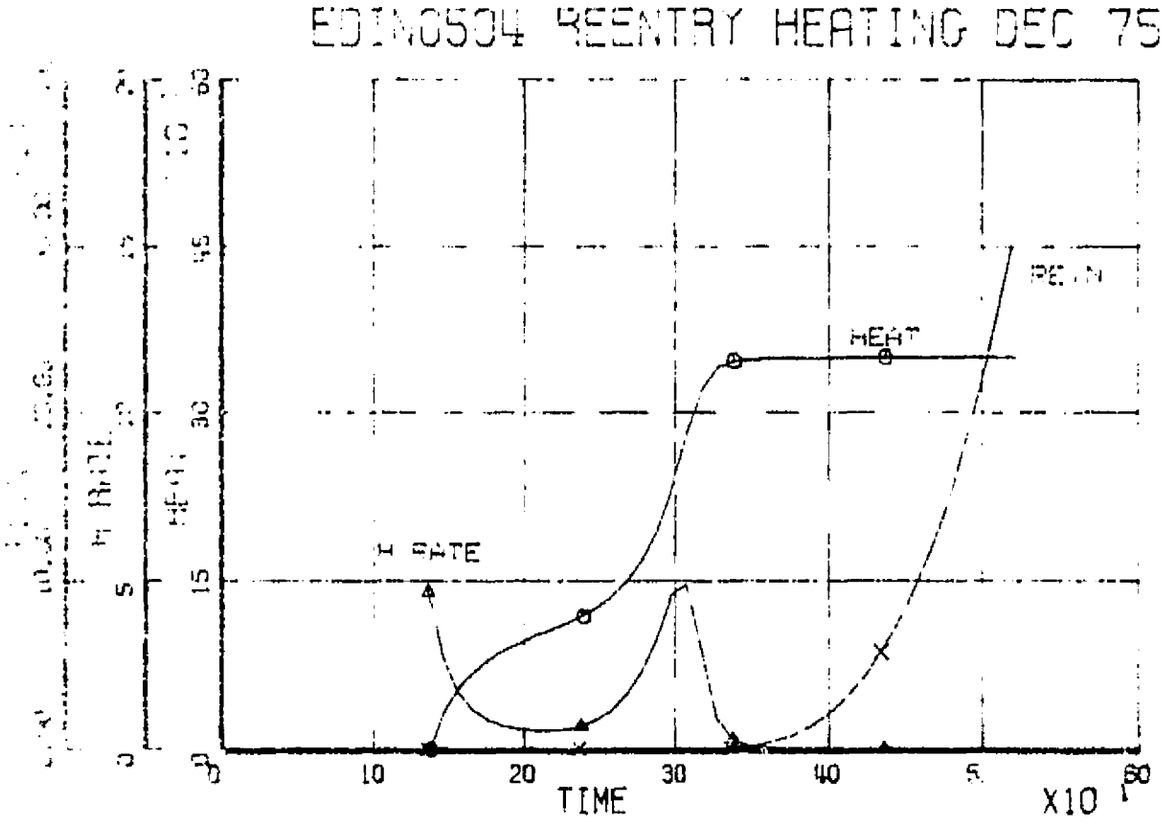
REL V
ALT
REL GAM
ORIGINAL PAGE IS
OF POOR QUALITY
TIME
X10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HEAT
H RATE
TIME
X10

EDIN0504D DESIGN

SIMULATION RESULTS

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**********************************************************************
FORECASTER: EDIN DESIGN CENTER                          DATE: 9 DEC 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC          TIME: 19:49
STUDY NO: EDIN0504
**********************************************************************

.
CONCEPT:      A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 4.000 F-1
              ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR REPLACEMENT
              OF THE SOLID ROCKET BOOSTERS.

.
MISSION:      MAXIMUM PAYLOAD
              DUE EAST LAUNCH FROM ETR
              A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL
              MILE REFERENCE ORBIT.
              A 100 FPS RCS TRANSLATION DELTA VEL.

.
TRAJECTORY:   DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH
              PROFILE AND INITIAL TILT RATE.
                 MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS/AOA
                 END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO
              ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY ONE F1
              ENGINE SHUTDOWN AND/OR SSME THROTTLING.
                 MAX DYNAMIC PRESSURE = 650.0 PSF
                 MAX ACCELERATION     = 3.0 G

.
PROPULSION:   LRB: 4.000 F-1 ENGINES RATED AT FOLLOWS:
                 THRUST(SL)  = 1906788.5 LBS
                 THRUST(VAC) = 1748060.0  LBS
                 ISP(SL)     = 266.01 SEC.
                 ISP(VAC)    =1289.40 SEC.
                 FLOWRATE    = 6040.3 LB/SEC
                 EXIT AREA   = 66.763 SQ FT
                 MIX RATIO   = 2.27:1
              ORBITER: THREE SSME ENGINES RATED AT FOLLOWS:
                 THRUST(SL)  = 375000.00 LBS
                 THRUST(VAC) = 470000.00 LBS
                 THROTTLE    = 1.09 TO .500
                 ISP(SL)     = 363.20 SEC
                 ISP(VAC)    = 455.20 SEC
                 FLOWRATE    = 1032.5 LB/SEC
                 EXIT AREA   = 44.896 SQ FT
                 MIX RATIO   = 6.00:1

.
AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION
              WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS
              WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
                 REF AREA    = 2557.0 SQ FT

.
STRUCTURE:    ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS
              ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND
              INCREASED UP PAYLOADS.

.
MASS          MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC
PROPERTIES:   ASSUMPTIONS.
                 LRB: WERE BASED ON SATURN TECHNOLOGY.
                 ET: FIXED MASS FRACTION DISTRIBUTED IN
                     ACCORDANCE WITH SHUTTLE ET WEIGHT
                     STATEMENT.
                 ORBITER: FEB 1975 SHUTTLE WITH MODS FOR
                     INCREASED UP PAYLOAD.
```
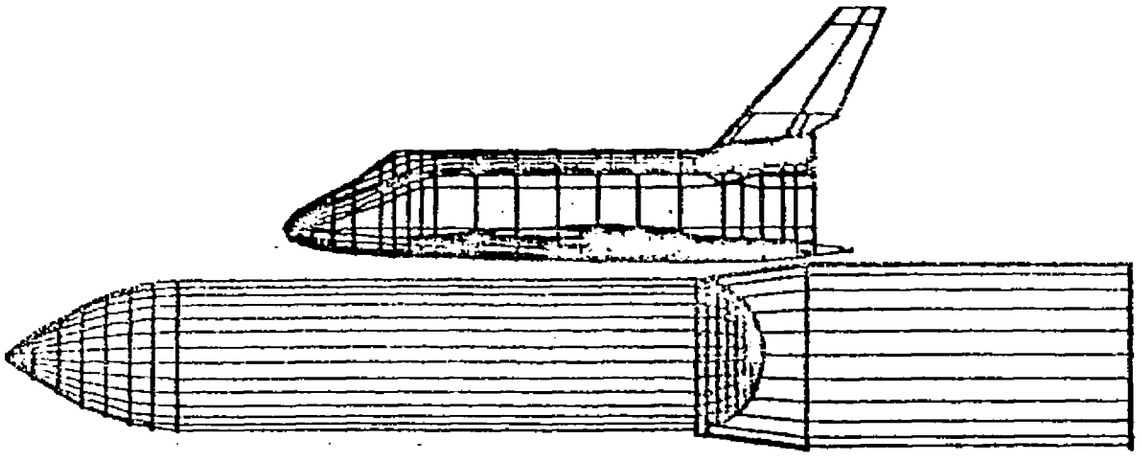

EDIN0504D DESIGN SIMULATION RESULTS



WEIGHTS SUMMARY REPORT

GLOW		4344480.00
ET LIFT-OFF WEIGHT		1323613.39
ET INERT WEIGHT	75160.790	
ET PROPELLANT	1248452.60	
LRB LIFT-OFF WEIGHT		2760267.72
LRB INERT WEIGHT	292011.79	
LRB PROPELLANT	2468255.91	
ORBITER LIFT-OFF WEIGHT		260579.00
ORBITER INERT WEIGHT	187254.00	
PAYLOAD	73325.000	

ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2862.	
BODY GROUP	43891.	
INDUCED ENVIRN PROTECT	19874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	28054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2929.	
ELECTRICAL CONVERSION	6960.	
HYDRAULIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 100K PAYLD	390.	
ORBITER EMPTY WEIGHT		151715.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1840.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16149.	
ORBITER INERT WEIGHT		187254.
PAYLOAD		72325.
ORBITER PRELAUNCH WEIGHT		260579.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		12153.
BHD	59.	
FWD FRAME	38.	
FWD OGIVE	1003.	
AFT OGIVE	3372.	
XT 745 FRAME	234.	
BARREL	2180.	
INTERTANK FRAME	796.	
AFT DOME	2593.	
SLOSH BAFFLES	1879.	
INTERTANK		9498.
MACHINED BARREL PNLS	3803.	
SK/STGR BARREL PNLS	4111.	
STABILIZING FRAMES(4)	1125.	
SRB THRST PT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	51.	
BARREL PNL SPLICES (8)	84.	
FRAME STABILIZERS	182.	
ET ASSY FASTENERS	142.	

LH2 TANK		39814.
FWD DOME	1488.	
WT 1128.9 FRAME	1402.	
BARREL NO.4	4877.	
WT 1377 FRAME	489.	
BARREL NO.3	4903.	
WT 1624 FRAME	489.	
BARREL NO.2	4905.	
WT 1871 FRAME	1537.	
BARREL NO.1	5198.	
WT 2058 FRAME	2937.	
AFT DOME	1663.	
THERMAL PROTECTION		5777.
LOX TANK	1839.	
INTERTANK	1884.	
LH2 TANK	3617.	
PROP (MECH+ELEC)	235.	
PROPULSION AND MECHANICAL SYSTEMS		3366.
LOX FEED SYS	1439.	
LOX ANTIGEYER SYS	135.	
LOX VENT SYS	76.	
LOX PRESS. SYS	164.	
LH2 FEED SYS	412.	
LH2 RECIR. SYS	27.	
LH2 VENT SYS	115.	
LH2 PRESS. SYS	121.	
HELIUM INJ. SYS	19.	
INTERTANK PURGE SYS	71.	
HAZARD GAS DETECTION SYS	7.	
FAIRINGS AND CONDUIT	304.	
LINE SUPTS. AND ATTACH.	476.	
ELECTRICAL SYSTEM		208.
ET WIRING ASSY	141.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	13.	
CABLING ATTACHS.+SENSOR SUPTS.	55.	
ORB/SRB ATTACHMENTS		4004.
ORBITER SUPPORTS	2748.	
UMBILICAL BEAM	563.	
ORB/ET ATTACH FTGS	209.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	484.	
MANUFACTURING VARIATION WT.		378.
EMPTY WEIGHT		65199.
UNUSABLE FLUIDS		364.
LH2 IN TANK	204.	
LH2 IN LINE	42.	
LOX IN LINE	117.	
PRE-PRESS.+INFLIGHT GASES		3293.
GH2	856.	
GOX	2409.	
HELIUM	28.	
SEPARATION HARDWARE		4.
SRB SUPPORTS	0.	
ORB FITTINGS	4.	
FLT PERF RES		6001.
ET INERT WT		75161.
MAIN PROPELLANTS		1 [illegible]3813.
LOX	1[illegible]3895.	
LH2	382316.	
ET LIFT-OFF WEIGHT		1 [illegible]1373.
MASS FRACTION (BASED ON INERT WEIGHT		.94433

LIQUID ROCKET BOOSTER WEIGHT STATEMENT:

BODY STRUCTURE		103821.
INTEGRAL LOX TANK	22433.	
INTEGRAL FUEL TANK	13813.	
INTERSTAGE	6583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	42833.	
AERODYNAMIC SURFACES		6816.
STABILIZERS (DRAG FLAPS)	6816.	
THERMAL PROTECTION SYSTEM		2282.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1381.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		820.
ELECTRICAL SYSTEM	702.	
CONTROL SYSTEM	118.	
INSTRUMENTATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		115290.
ENGINES (DRY)	76152.	
ACCESSORIES	555.	
GIMBAL SYSTEM	7044.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	11185.	
OXIDIZER SYSTEM	16098.	
SEPARATION AND RECOVERY SYSTEM		16667.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	5725.	
FLOATATION SYSTEM	104.	
RECOVERY AIDS	102.	
FITTINGS AND SUPPORTS	197.	
RETRO SYS (100 F/S DEL V)	3174.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		247356.
CONTINGENCY		0.
EMPTY WEIGHT		247356.
PROPELLANT RESIDUALS		40408.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	4199.	
TRAPPED FUEL TANK GASES	3388.	
FROST TRAPPED	454.	
TRAPPED FUEL	12764.	
TRAPPED LOX	17803.	
IN-FLIGHT LOSSES		4248.
FUEL LOSSES	2053.	
LOX LOSSES	2195.	
LRB INERT WT		292012.
MAIN PROPELLANTS		2468256.
FUEL	754818.	
LOX	1713438.	
BLOW		2760268.
MASS FRACTION (BASED ON INERT WT)		.8942

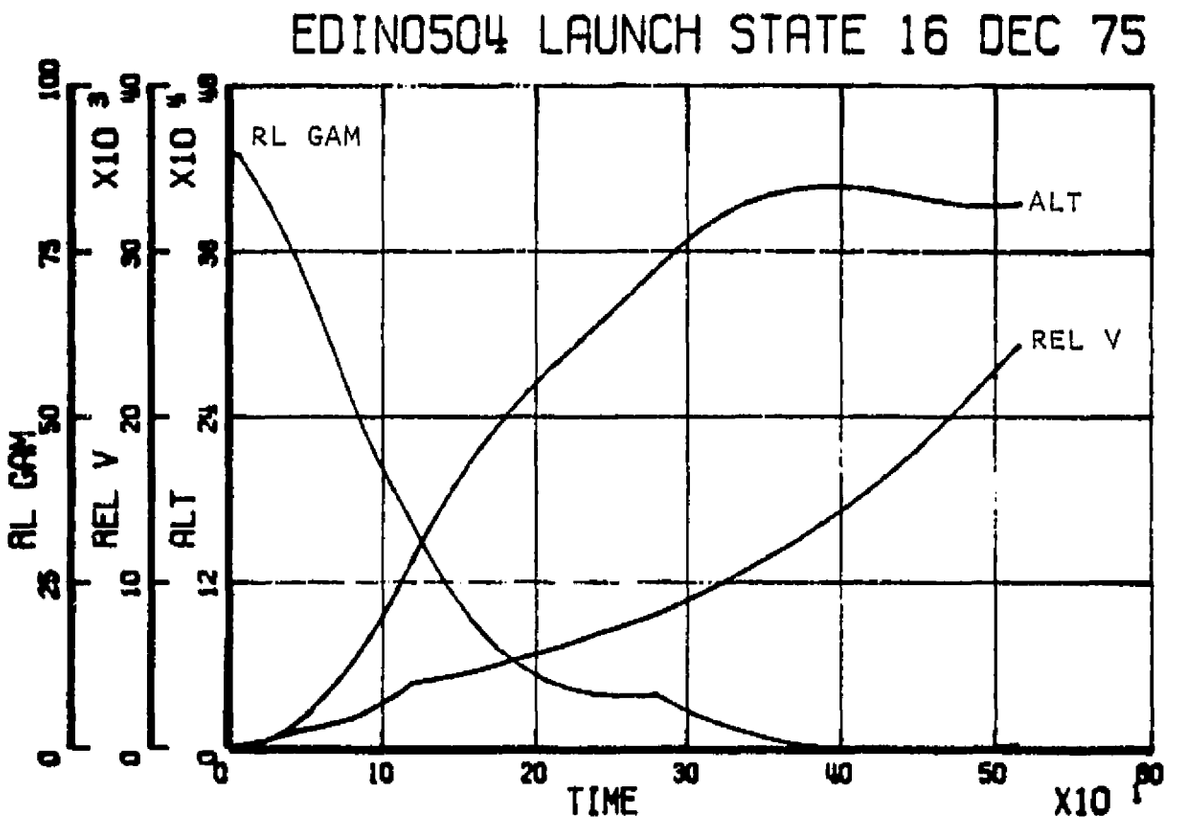
ORBITER WT	240579.0
ET WEIGHT	1323613.4
LRB WEIGHT	2760267.7
GLOW	4344460.1
STG 1 LAMBDA	.89421
STG 2 LAMBDA	.94438

```
CONVERGENCE DATA:
      SLOW                                    4344460.
         ACTUAL PAYLOAD                                    73388.
      TOTAL VIDEAL                             30386.5
         STAGE 1 VIDEAL                                  7603.3
         STAGE 2 VIDEAL                                 22782.7
      TOTAL PROPELLANT                        3716706.
         LRB PROPELLANT                                2468256.
         ET PROPELLANT                                 1248450.
      STAGE JETTISON WEIGHTS
         STAGE 1 JETTISON WT                            292013.
         STAGE 2 JETTISON WT                             75161.

STAGE 1 SIZING DATA
      AVERAGE SP. IMP.                          281.47
      LIFT-OFF T/W                               1.479
      MAXIMUM Q                                  646.1
      TIME AT MAX Q                               45.7
      STG 1 MAX LF                                2.76
      TIME AT MAX LF                             120.0
      EFF WDOT/LRB                             20405.5
      EFF WDOT/EVENT 1                         20405.5

STAGING CONDITIONS:
      WEIGHT                                  1376204.
      REL VELOCITY (FPS)                        3956.7
      REL F.P. ANGLE (DEG)                       34.44
      ALTITUDE (FT)                            137056.
      TIME (SEC)                                120.96
      ATT AFTER STG (DEG)                         1.24
```

MISSION SUMMARY

PARAMETER	EVENT 1	EVENT 2	EVENT 3	EVENT 4	EVENT 5
TIME (SEC)	45.75	121.0	281.1	517.2	467.0
ALTITUDE (K FT)	20.5	137.1	348.6	394.6	0
REL VELOCITY (100 FPS)	10.3	39.6	81.4	243.0	2.25
REL GAMMA (DEG)	73.8	34.4	8.27	.528	-89.8
WEIGHT (K LBS)	4344.5	3239.1	1584.2	1043.3	292.0
WEIGHT DROP (K LBS)	0	292.0	0	75.2	0
THROW WEIGHT (K LBS)	3239.1	1584.2	1043.3	260.6	0
CUM VIDEAL (100 FPS)		76.0	137.2	303.3	0
DOWNRANGE (NMI)	0.65	19.98	186.5	826.7	110.9

EVENT 1 ONE F-1 ENGINE SHUTDOWN
EVENT 2 BECO/SEPARATION
EVENT 3 RTLS/AOA CONSTRAINT
EVENT 4 MECO/INJECTION
EVENT 5 LRB TOUCHDOWN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REL V
RL GAM
REL V
ALT
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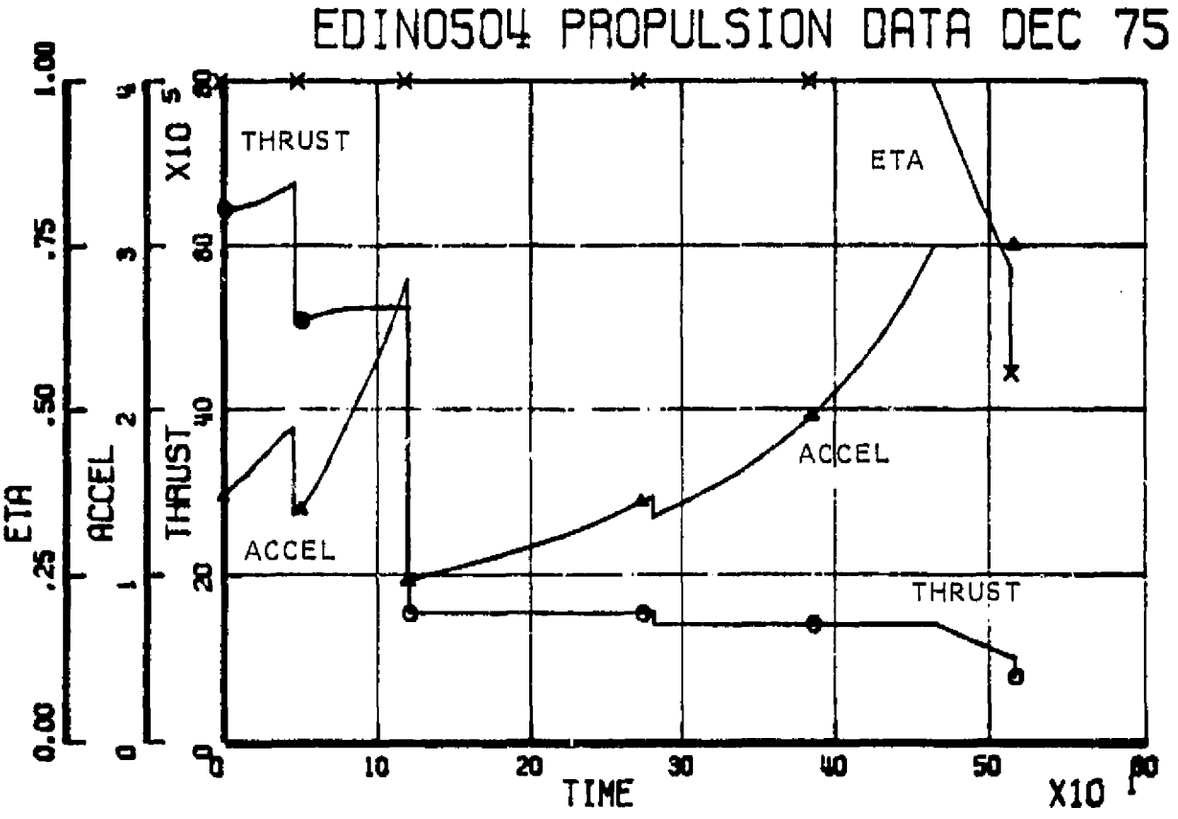
X10 4
TIME
X10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ETA
ACCEL
ACCEL
THRUST
ETA
ACCEL
THRUST
X10 5
TIME
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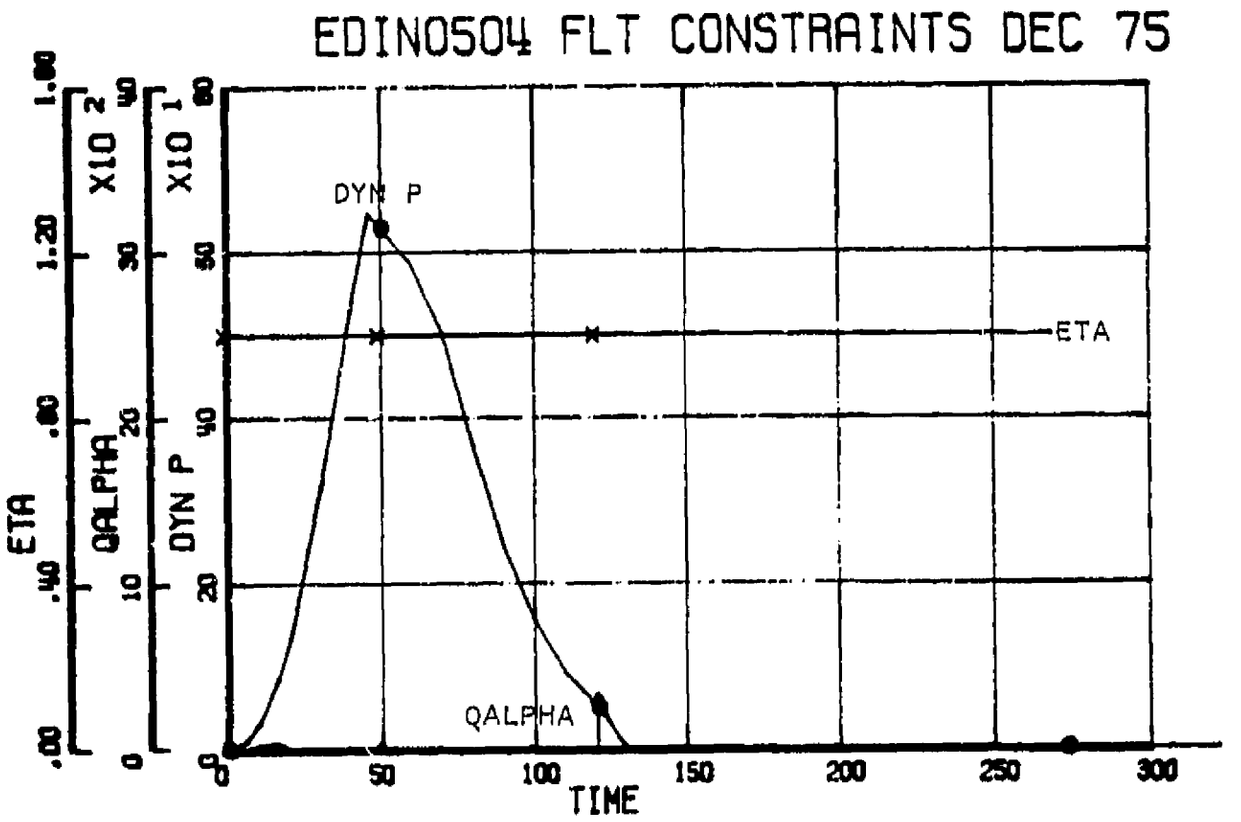
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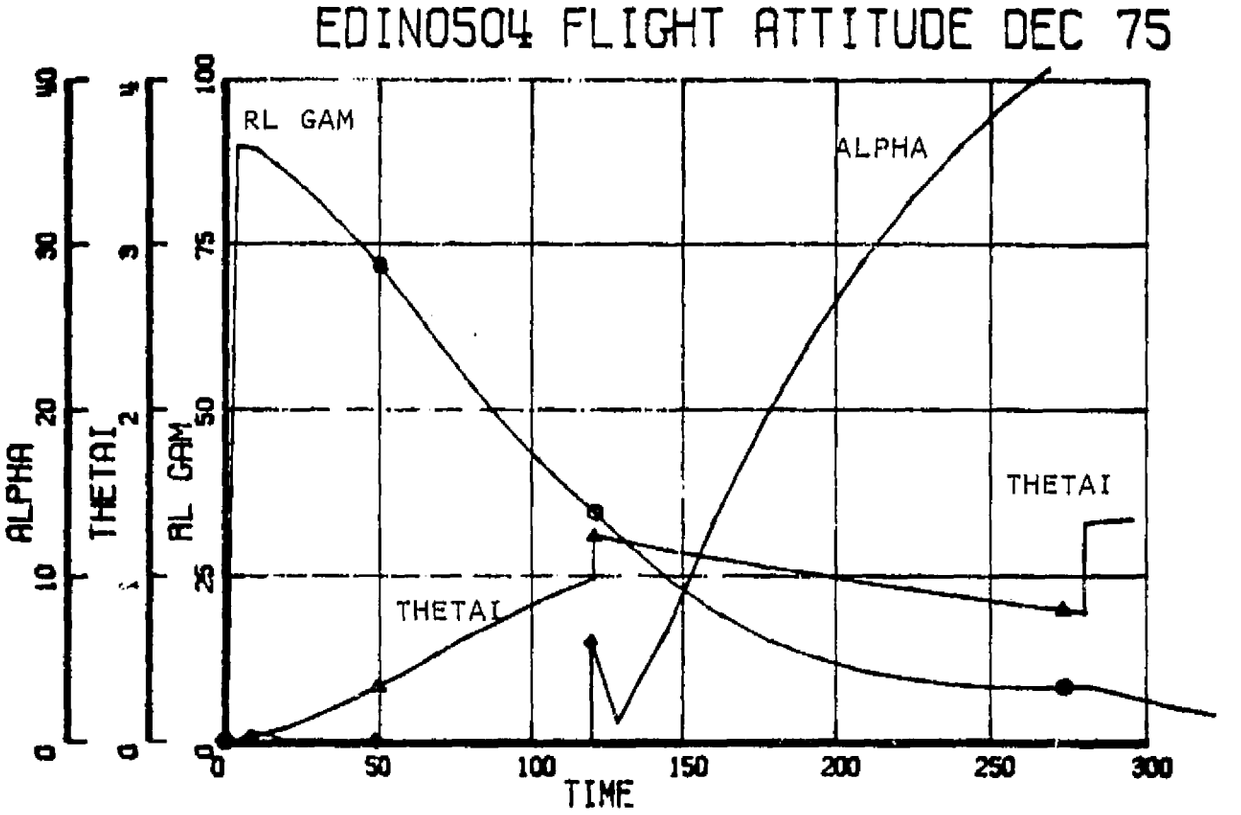
ETA
QALPHA X10 2
DYN P X10 1
DYN P
ETA
QALPHA
TIME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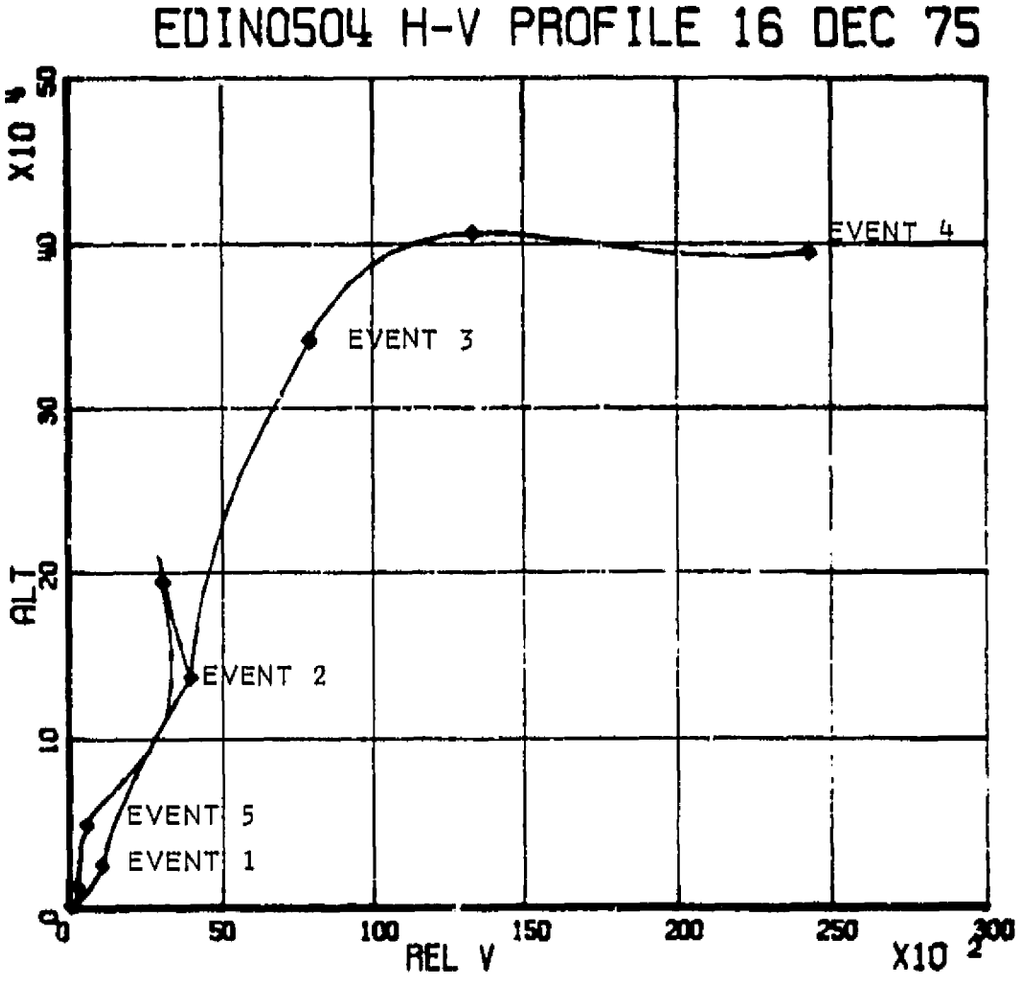
THETAI
RL GAM
RL GAM
ALPHA
THETAI
THETAI
TIME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X10 4
50
40
30
20
10
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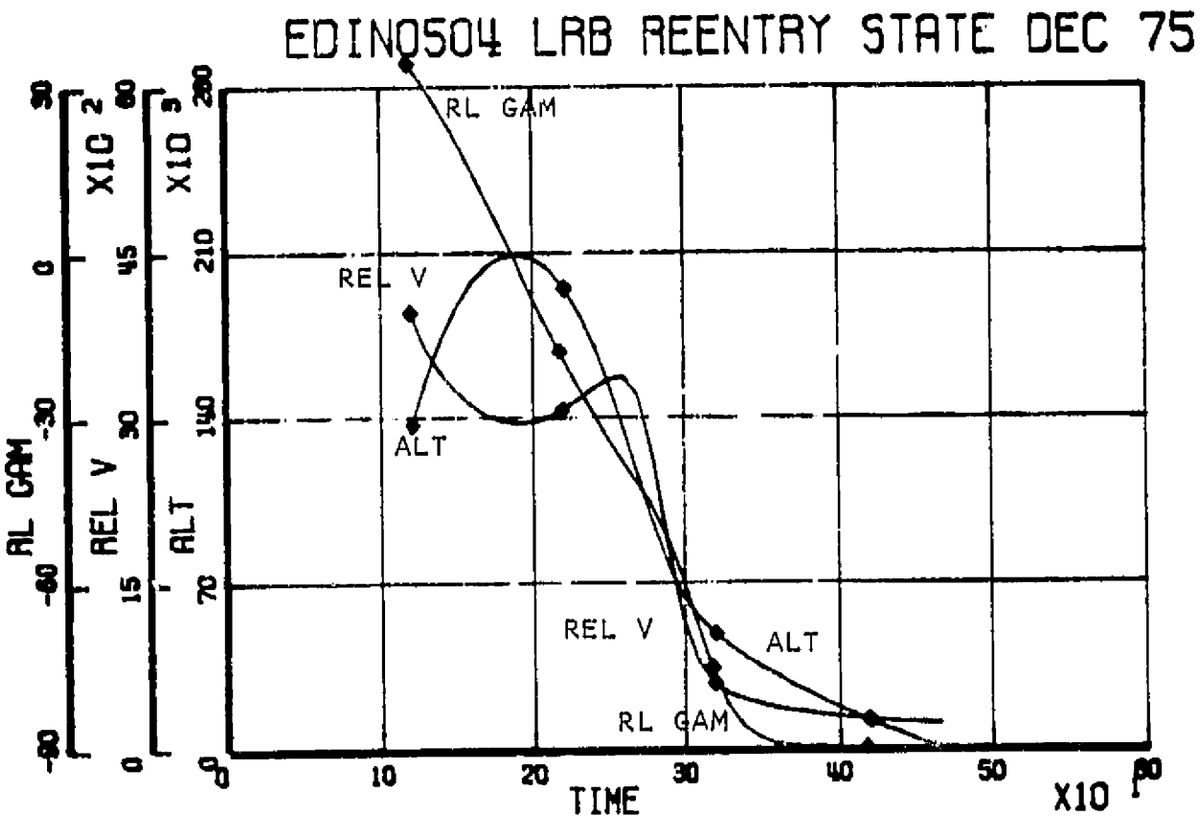
ALT
EVENT 4
EVENT 3
EVENT 2
EVENT 5
EVENT 1
0
50
100
150
200
250
300
REL V
X10 2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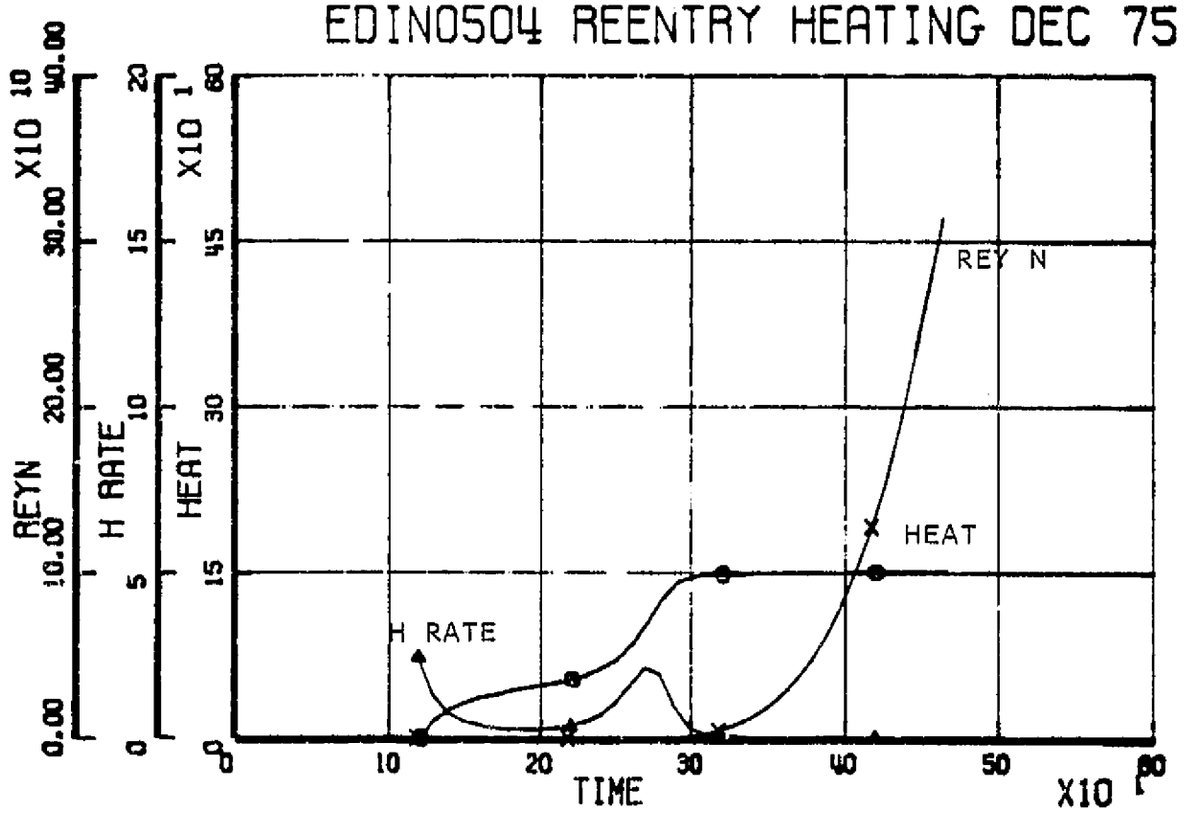
REL V
ALT
REL V
ALT
RL GAM
RL GAM
X10 2
REL V
X10 3
ALT
TIME
X10


EDIN0504 REENTRY HEATING DEC 75
X10 10
REYN
X10 1
H RATE
HEAT
REY N
HEAT
H RATE
TIME
X10

SIGMA CORPORATION

EDINO505 DESIGN

SIMULATION RESULTS

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FORECASTER: EDIN DESIGN CENTER                          DATE: 24 NOV 75
AFFILIATION: ENGINEERING ANALYSIS DIVISION/JSC          TIME: 09:40
STUDY NO: EDIN0505

CONCEPT:      A 33.0 FT. DIAMETER RECOVERABLE STAGE USING 4.000 F-1
              ENGINES MOUNTED BEHIND THE SHUTTLE ET FOR REPLACEMENT
              OF THE SOLID ROCKET BOOSTERS.

MISSION:      100000.0 LB PAYLOAD
              DUE EAST LAUNCH FROM ETR
              A 250 FPS OMS DELTA VEL IN EXCESS OF A 50X100 NAUTICAL
              MILE REFERENCE ORBIT.
              A 100 FPS RCS TRANSLATION DELTA VEL.

TRAJECTORY:   DUAL CONSTRAINT OPTIMIZED EXO-ATMOSPHERIC PITCH
              PROFILE AND INITIAL TILT RATE.
                 MID POINT CONSTRAINT = SHUTTLE MISSION 1 RTLS/AOA
                 END POINT CONSTRAINT = SHUTTLE MISSION 1 MECO
              ATMOSPHERIC INFLIGHT CONSTRAINTS CONTROLLED BY ONE F1
              ENGINE SHUTDOWN AND/OR SSME THROTTLING.
                 MAX DYNAMIC PRESSURE = 650.0 PSF
                 MAX ACCELERATION     = 3.0 G

PROPULSION:   LRB: 4.000 F-1 ENGINES RATED AS FOLLOWS:
                 THRUST(SL)  = 1606788.5 LBS
                 THRUST(VAC) = 1748060.0  LBS
                 ISP(SL)     = 266.01 SEC.
                 ISP(VAC)    = 289.40 SEC.
                 FLOWRATE    = 6040.3 LB/SEC
                 EXIT AREA   = 66.763 SQ FT
                 MIX RATIO   = 2.27:1
              ORBITER: THREE SSME ENGINES RATED AS FOLLOWS:
                 THRUST(SL)  = 375000.00 LBS
                 THRUST(VAC) = 470000.00 LBS
                 THROTTLE    = 1.09 TO .500
                 ISP(SL)     = 363.20 SEC
                 ISP(VAC)    = 455.20 SEC
                 FLOWRATE    = 1032.5 LB/SEC
                 EXIT AREA   = 44.896 SQ FT
                 MIX RATIO   = 6.00:1

AERODYNAMICS: DATA FOR LAUNCH PERFORMANCE OPTIMIZATION
              WERE OBTAINED FROM SHUTTLE AERO ESTIMATES. ADJUSTMENTS
              WERE MADE TO THE REFERENCE AREA FOR SRB DELETION.
                 REF AREA    = 2557.0 SQ FT

STRUCTURE:    ORBITER AND EXTERNAL TANK STRUCTURAL WEIGHT MODIFICATIONS
              ARE INCLUDED FOR DELETION OF THE SRB/ET ATTACHMENTS AND
              INCREASED UP PAYLOADS.

MASS          MASS PROPERTIES ARE BASED ON THE FOLLOWING BASIC
PROPERTIES:   ASSUMPTIONS.
                 LRB: WERS BASED ON SATURN TECHNOLOGY.
                 ET: FIXED MASS FRACTION DISTRIBUTED IN
                     ACCORDANCE WITH SHUTTLE ET WEIGHT
                     STATEMENT.
                 ORBITER: FEB 1975 SHUTTLE WITH MODS FOR
                     INCREASED UP PAYLOAD.
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ORBITER WEIGHT STATEMENT FOR MISSION 1:

WING GROUP	15684.	
TAIL GROUP	2862.	
BODY GROUP	43291.	
INDUCED ENVIRN PROTECT	19874.	
LANDING & AUX SYSTEMS	7683.	
PROPULSION-ASCENT	28054.	
PROPULSION-RCS	2657.	
PROPULSION-OMS	2902.	
PRIME POWER	2929.	
ELECTRICAL CONVERSION	6960.	
HYDRAULIC CONVERSION	1840.	
SURFACE CONTROLS	2739.	
AVIONICS	5778.	
ENVIRONMENTAL CONTROL	5060.	
PERSONNEL PROVISION	1100.	
PAYLOAD PROVISIONS	585.	
MARGIN	1327.	
WT PENALTY FOR 100K PAYLD	390.	
ORBITER EMPTY WEIGHT		151715.
PERSONNEL	2644.	
RESIDUALS	1470.	
RESERVE FLUIDS	1840.	
INFLIGHT LOSSES	2171.	
ASCENT PROPULSION	5024.	
PROPELLANT-RCS	6241.	
PROPELLANT-OMS	16149.	
ORBITER INERT WEIGHT		187254.
PAYLOAD		100000.
ORBITER PRELAUNCH WEIGHT		287254.

EXTERNAL TANK WEIGHT STATEMENT:

LOX TANK		11897.
BHD	58.	
FWD FRAME	37.	
FWD OGIVE	982.	
AFT OGIVE	3301.	
XT 745 FRAME	229.	
BARREL	2134.	
INTERTANK FRAME	779.	
AFT DOME	2538.	
SLOSH BAFFLES	1839.	
INTERTANK		9298.
MACHINED BARREL PNLS	3723.	
SK/STGR BARREL PNLS	4024.	
STABILIZING FRAMES(4)	1101.	
SRB THRST XT 985 FRAME	0.	
SRB THRST BEAM	0.	
SRB THRST FITTINGS (2)	0.	
ACCESS DOOR	50.	
BARREL PNLS SPLICES (8)	82.	
FRAME STABLIZERS	178.	
ET ASSY FASTENERS	139.	

LH2 TANK		29187.
FWD DOME	1398.	
XT 1129.9 FRAME	1374.	
BARREL NO.4	4774.	
XT 1377 FRAME	479.	
BARREL NO.3	4800.	
XT 1624 FRAME	479.	
BARREL NO.2	4802.	
XT 1871 FRAME	1504.	
BARREL NO.1	5079.	
XT 2058 FRAME	3875.	
AFT DOME	1628.	
THERMAL PROTECTION		5655.
LOX TANK	1213.	
INTERTANK	1259.	
LH2 TANK	2954.	
PROP (MECH+ELEC)	230.	
PROPULSION AND MECHANICAL SYSTEMS		3295.
LOX FEED SYS	1409.	
LOX ANTIGEYER SYS	132.	
LOX VENT SYS	74.	
LOX PRESS. SYS	160.	
LH2 FEED SYS	403.	
LH2 RECIR. SYS	26.	
LH2 VENT SYS	112.	
LH2 PRESS. SYS	119.	
HELIUM INJ. SYS	18.	
INTERTANK PURGE SYS	70.	
HAZARD GAS DETECTION SYS	7.	
FAIRINGS AND CONDUIT	298.	
LINE SUPTS. AND ATTACHS.	466.	
ELECTRICAL SYSTEM		204.
ET WIRING ASSY	138.	
SRB WIRING ASSY	0.	
INSTRUMENTATION	13.	
CABLING ATTACHS.+SENSOR SUPTS.	53.	
ORB/SRB ATTACHMENTS		3920.
ORBITER SUPPORTS	2690.	
UMBILICAL BEAM	552.	
ORB/ET ATTACH FTGS	205.	
SRB/ET ATTACH FTGS	0.	
ET/ORB UMBILICAL HDWR	474.	
MANUFACTURING VARIATION WT.		370.
EMPTY WEIGHT		63827.
UNUSABLE FLUIDS		356.
LH2 IN TANK	200.	
LH2 IN LINE	41.	
LOX IN LINE	115.	
PRE-PRESS.+INFLIGHT GASES		3223.
GH2	838.	
GOX	2358.	
HELIUM	27.	
SEPARATION HARDWARE		4.
SRB SUPPORTS	0.	
ORB FITTINGS	4.	
FLT PERF RES		5574.
ET INERT WT		72985.
MAIN PROPELLANTS		1249368.
LOX	1070887.	
LH2	178481.	
ET LIFT-OFF WEIGHT		1322353.
MASS FRACTION		.9490

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LIQUID ROCKET BOOSTER WEIGHT STATEMENT:		
BODY STRUCTURE		69663.
INTEGRAL LOX TANK	24101.	
INTEGRAL FUEL TANK	16337.	
INTERSTAGE	8583.	
AFT SKIRT	16159.	
THRUST STRUCTURE	4482.	
AERODYNAMIC SURFACES		6916.
STABILIZERS (DRAG FLAPS)	6916.	
THERMAL PROTECTION SYSTEM		2305.
TANK INSULATION	941.	
ABLATIVE MATERIAL	1364.	
POWER SUPPLY/CONVERSION/DISTRIBUTION		873.
ELECTRICAL SYSTEM	748.	
CONTROL SYSTEM	126.	
INSTRUMENTATION SYSTEM		1520.
INSTRUMENTATION	1520.	
PROPULSION		114948.
ENGINES (DRY)	76152.	
ACCESSORIES	555.	
GIMBAL SYSTEM	7044.	
BASE HEAT SHIELD	4356.	
FUEL SYSTEM	11185.	
OXIDIZER SYSTEM	15656.	
SEPARATION AND RECOVERY SYSTEM		16847.
SEPARATION SYSTEM	2488.	
CHUTE SYS (MAIN AND DROGUE)	5836.	
FLOTATION SYSTEM	106.	
RECOVERY AIDS	104.	
FITTINGS AND SUPPORTS	201.	
RETRO SYS (100 F/S DEL V)	3236.	
REENTRY HEAT SHIELD	4876.	
STAGE DRY WEIGHT		213072.
CONTINGENCY		0.
EMPTY WEIGHT		213072.
PROPELLANT RESIDUALS		46991.
FUEL BIAS	1800.	
TRAPPED LOX TANK GASES	4511.	
TRAPPED FUEL TANK GASES	4008.	
FROST TRAPPED	505.	
TRAPPED FUEL	15103.	
TRAPPED LOX	21064.	
IN-FLIGHT LOSSES		5027.
FUEL LOSSES	2429.	
LOX LOSSES	2597.	
LRB INERT WT		265090.
MAIN PROPELLANTS		2920477.
FUEL	893112.	
LOX	2027365.	
BLOW		3185567.
MASS FRACTION (BASED ON INERT WEIGHT		.91678

ORBITER WT	287254.0
ET WEIGHT	1322353.4
LRB WEIGHT	3185567.2
GLOW	4795174.5
STG 1 LAMBDA	.91678
STG 2 LAMBDA	.94481

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CONVERGENCE DATA:
      GLOW                                    4795174.
      TARGET PAYLOAD                           100000.
         ACTUAL PAYLOAD                                    100363.
         PAYLOAD DELTA                                        362.7
      TOTAL VIDEAL                             30434.1
         STAGE 1 VIDEAL                                      8510.5
         STAGE 2 VIDEAL                                     21923.6
      TOTAL PROPELLANT                        4169554.
         LRB PROPELLANT                                   2918701.
         ET PROPELLANT                                    1250853.
         FIRST STAGE JETTISON WT                           264929.
         SECOND STAGE JETTISON WT                           73075.

STAGE 1 SIZING DATA
      AVERAGE SP. IMP.                          281.33
      LIFT-OFF T/W                               1.340
      MAXIMUM Q                                651.8
      TIME AT MAX Q                             62.5
      STG 1 MAX LF                               2.78
      TIME AT MAX LF                           140.0

STAGING CONDITIONS:
      WEIGHT                                  1876473.
      REL VELOCITY (FPS)                       4577.2
      REL F.P. ANGLE (DEG)                       24.39
      ALTITUDE (FT)                           149411.
      TIME (SEC)                               140.24
      ATT AFTER STG (DEG)                         .87
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                    WEIGHTS SUMMARY REPORT

GLOW                                                  4795174.50

ET LIFT-OFF WEIGHT                                    1322353.36

   ET INERT WEIGHT                        72985.36
   ET PROPELLANT                        1250852.73

LRB LIFT-OFF WEIGHT                                   3180567.19

   LRB INERT WEIGHT                      265090.01
   LRB PROPELLANT                       2918700.84

ORBITER LIFT-OFF WEIGHT                                287254.00

   ORBITER INERT WEIGHT                  187254.00
   PAYLOAD                               100000.00
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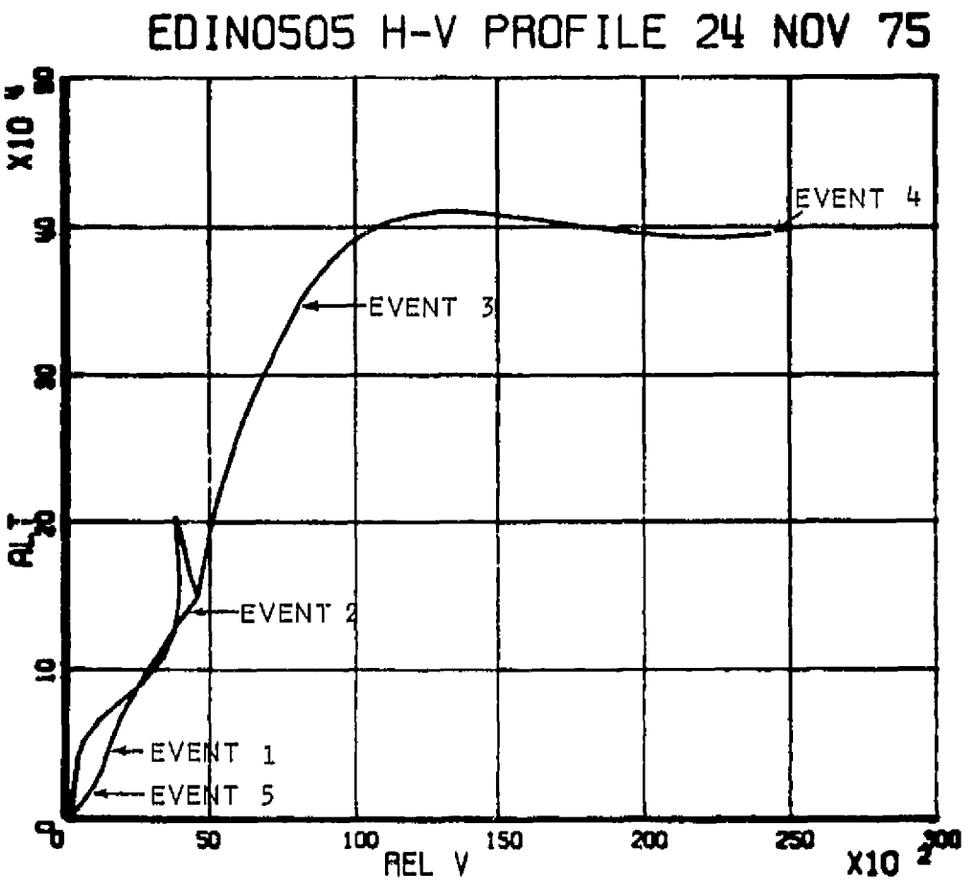

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MISSION SUMMARY: NOVEMBER 24, 1975

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PARAMETER	EVENT 1	EVENT 2	EVENT 3	EVENT 4	EVENT 5
TIME (SEC)	62.50	140.2	283.8	536.0	490.0
ALTITUDE (K FT)	30.75	149.4	348.6	394.5	0
REL VELOCITY (100 FPS)	12.2	45.8	81.4	243.0	2.15
REL GAMMA (DEG)	66.6	24.4	8.27	.527	-89.8
WEIGHT (K LBS)	4795.2	3285.1	1611.5	1126.9	264.9
WEIGHT DROP (K LBS)	0	264.9	0	73.08	0
THROW WEIGHT (K LBS)	3285.1	1611.5	1126.9	287.62	0
CUM VIDEAL (100 FPS)		85.10		304.3	0
DOWNRANGE (NMI)	1.38	28.97	187.7	865.3	136.0

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EVENT 1 ONE F-1 ENGINE SHUTDOWN
EVENT 2 BECO/SEPARATION
EVENT 3 RTLS/AOA CONSTRAINT
EVENT 4 MECO/INJECTION
EVENT 5 LRB TOUCHDOWN

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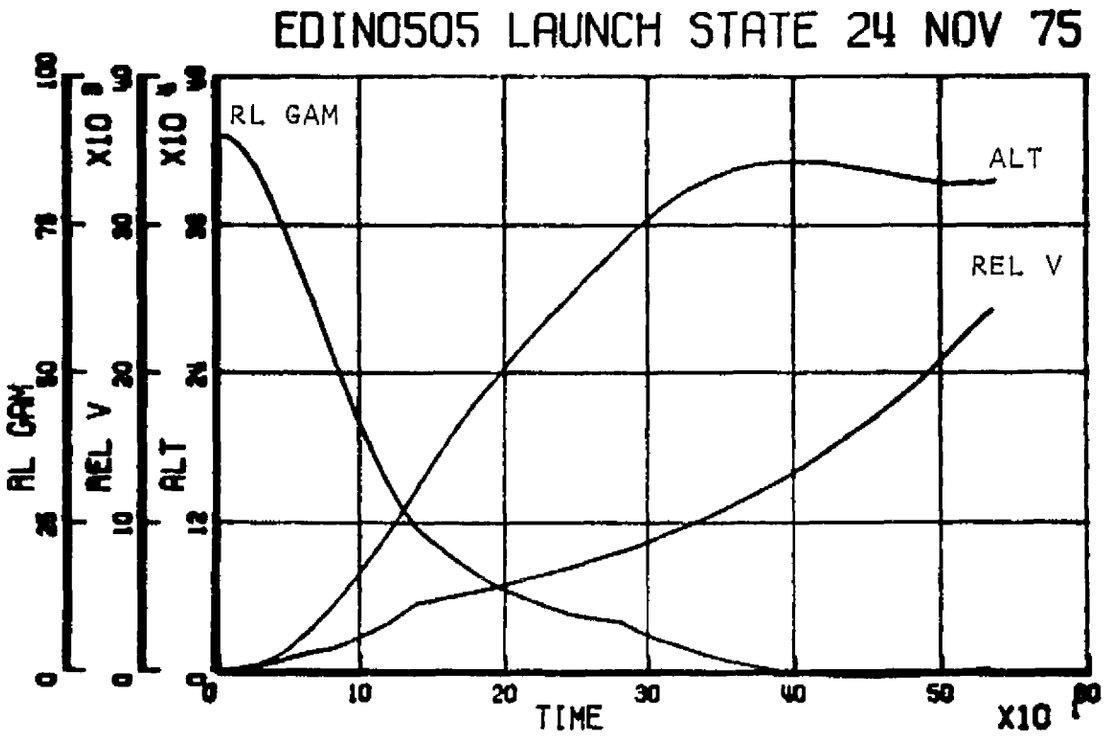
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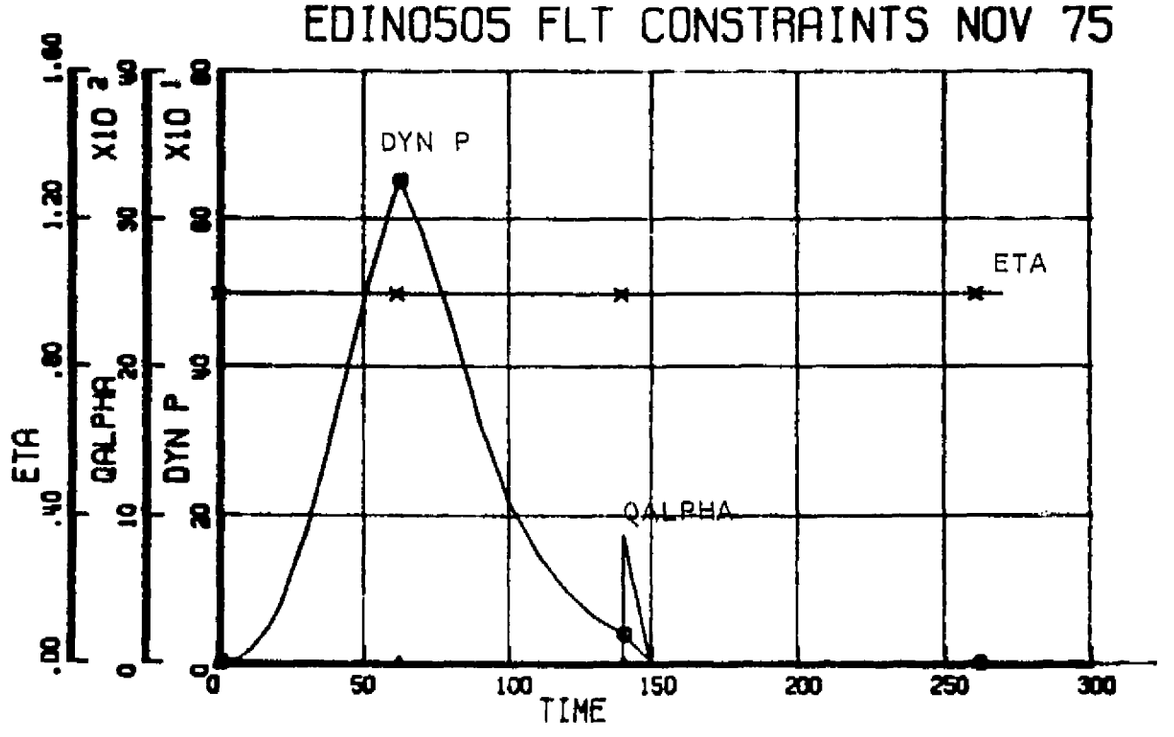
RL GAM
ALT
REL V
RL GAM
REL V
ALT
TIME
X10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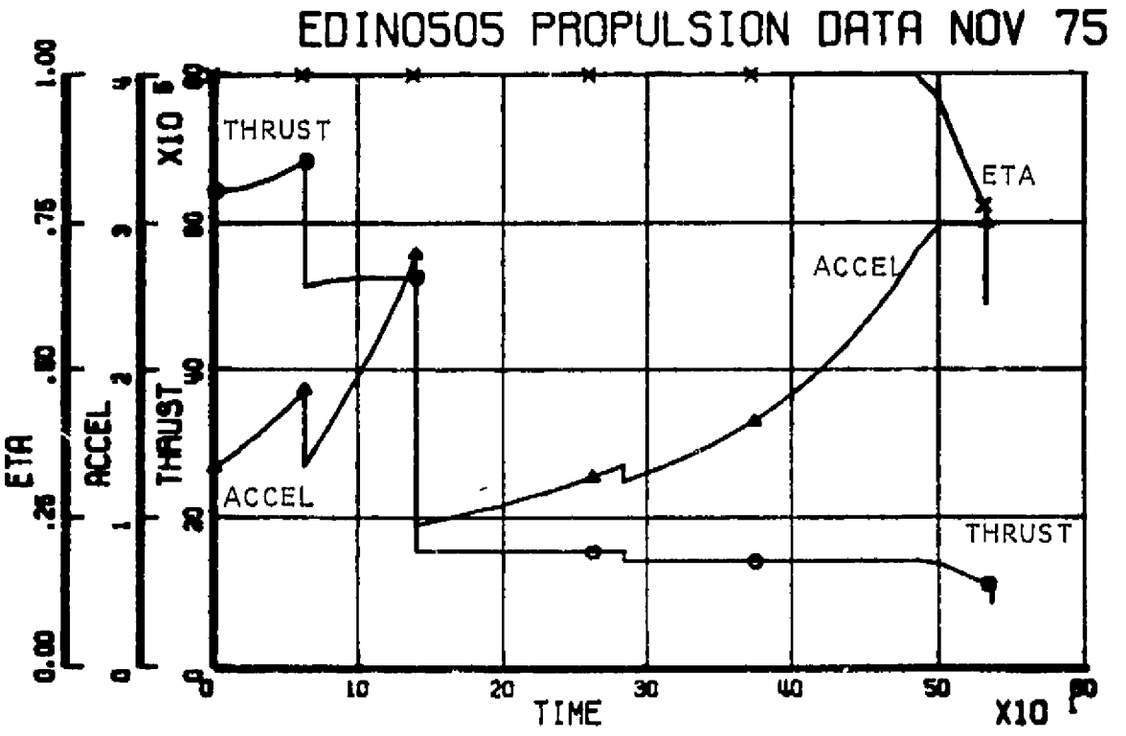
DYN P
ETA
QALPHA
ETA
QALPHA
DYN P
TIME


EDINOSOS PROPULSION DATA NOV 75
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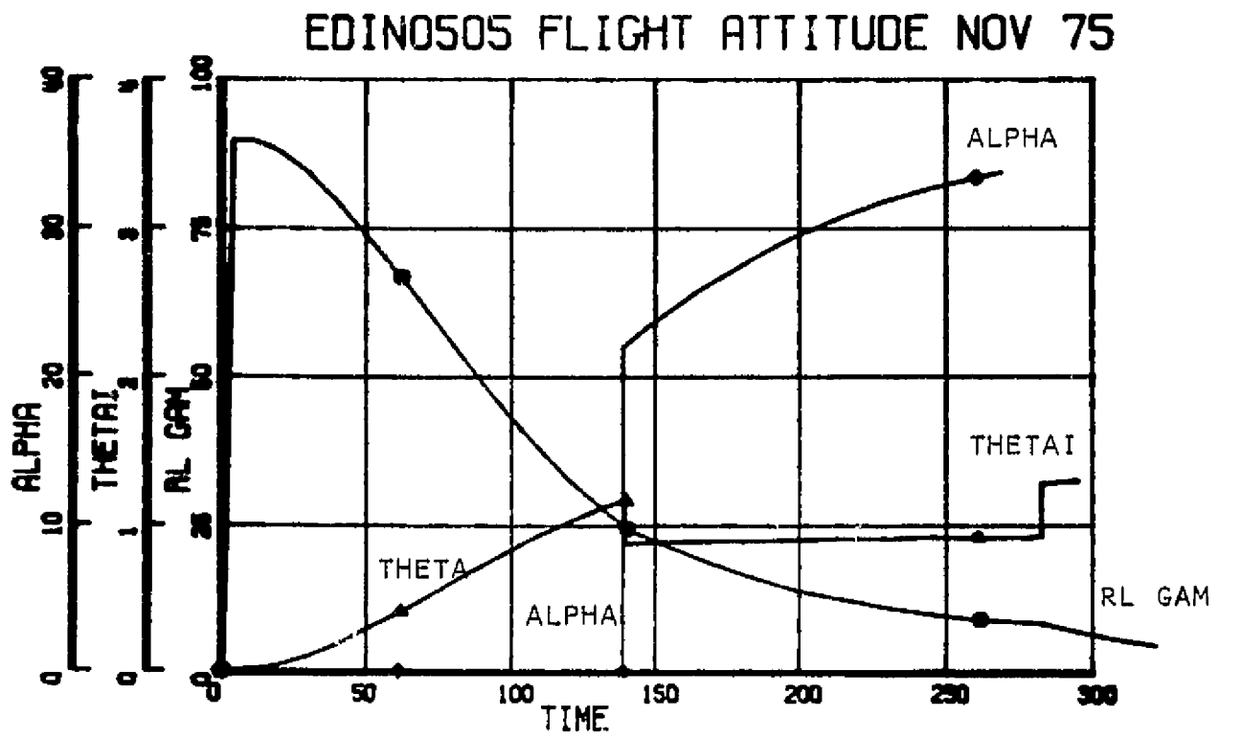
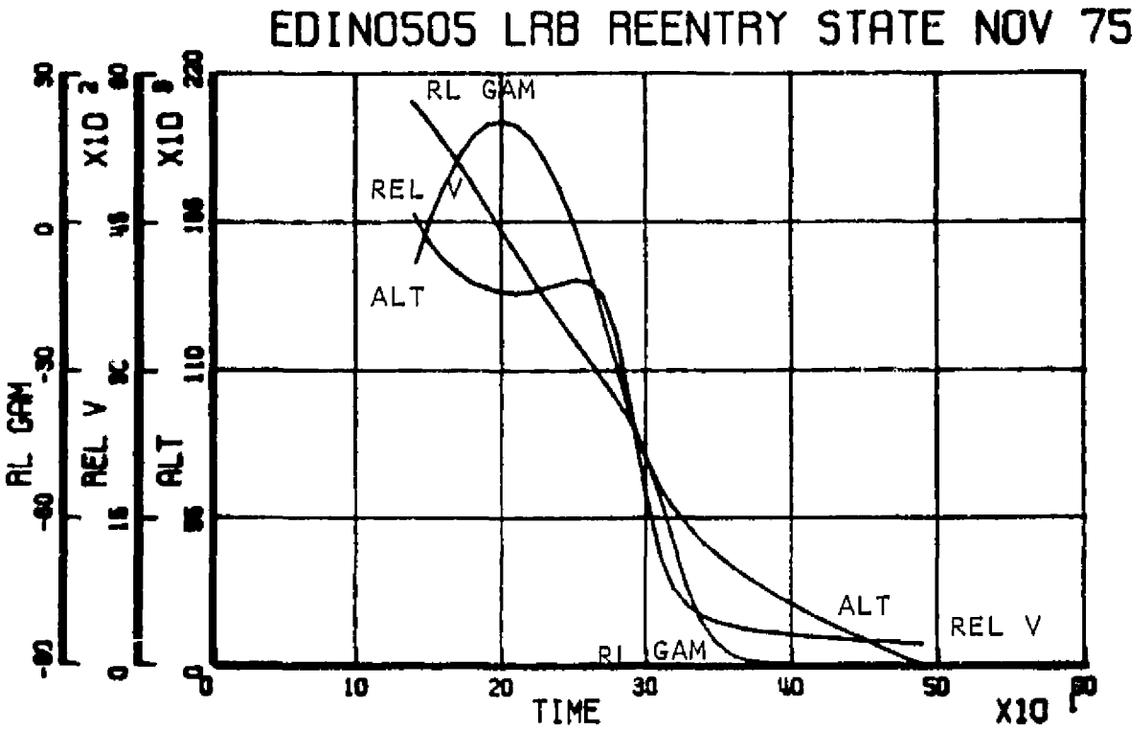
ETA
ACCEL
ACCEL
THRUST
ETA
ACCEL
THRUST
TIME
X10


EDINOSOS FLIGHT ATTITUDE NOV 75
ALPHA
THETAI
RL GAM
ALPHA
THETAI
THETA
ALPHA
RL GAM
TIME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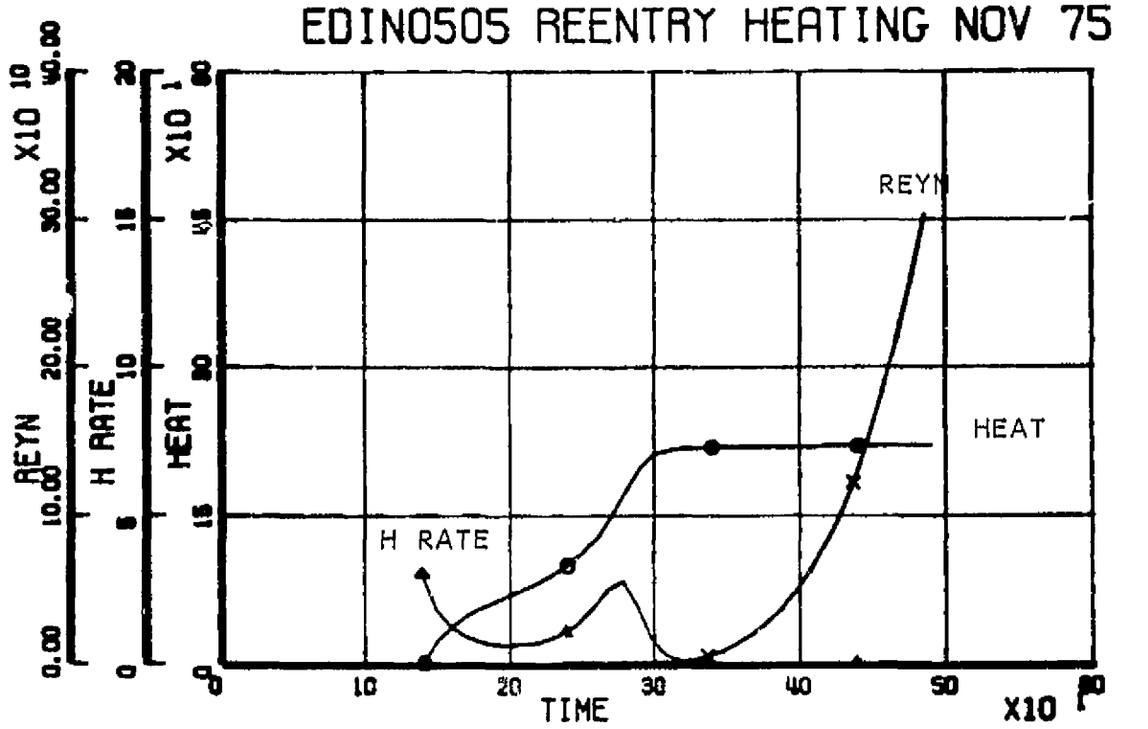
RL GAM
REL V
ALT
TIME
X10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REYN
HEAT
H RATE
TIME
X10